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DETAILED REPORT TO SOLVE AND IMPROVEMENT OF INTELLIGENT TRANSPORT SYSTEM

Submitted by

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ABSTRACT

This report provides an overview of the latest developments in Intelligent Transport Systems (ITS), with a particular focus on applications relevant to micro- simulation, including autonomous/semi-autonomous driving technologies and co- operative systems.Furthermore, there is a review of several examples where micro- simulation has been used to assess the impacts of ITS. Many ITS applications are currently being deployed, or are being sought to be deployed, and some form of verification or testing is required to assess their impact. There are several different approaches for doing this, of which micro-simulation appears to be one of the most powerful methods in some cases. This document is intended to be read in parallel with the accompanying report, which gives areview of the state-of-the-art in micro- simulation. The purpose of these two documents is to provide a baseline understanding of the state-of-the-art in ITS and micro- simulation.

CHAPTER – 1

INTRODUCTION

Intelligent Transportation Systems (ITS) is the use of Information Technology (IT), sensors and communications technologies for surface transport applications - though road transport applications vastly predominate. Road and other infrastructure building is expensive and environmentally unfriendly; we can make better use of the civil infrastructure by using a broad range of electronic technologies, making transportation systems safe, ecient, reliable and environmentally friendly, without implementing new physical infrastructure. ITS cuts across disciplines such as transportation, engineering, telecommunications, computer science, finance, electronic commerce and automotive manufacturing. Use of wireless/radio mobile communications and satellite positioning systems are particularly important. The ITS field probably has more than its fair share of acronyms. Where possible, each one will be explained when it is first introduced but a complete list will be found in section 12.1. ITS also a big subject, and what were previously distinct and separate areas are now starting to overlap, partly though the influence of mobile communications - as we will see in this Report.

An important metric for economic growth of any country is its burgeoning vehicle ownership. However, the indirect effect of vehicle ownership isacute 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

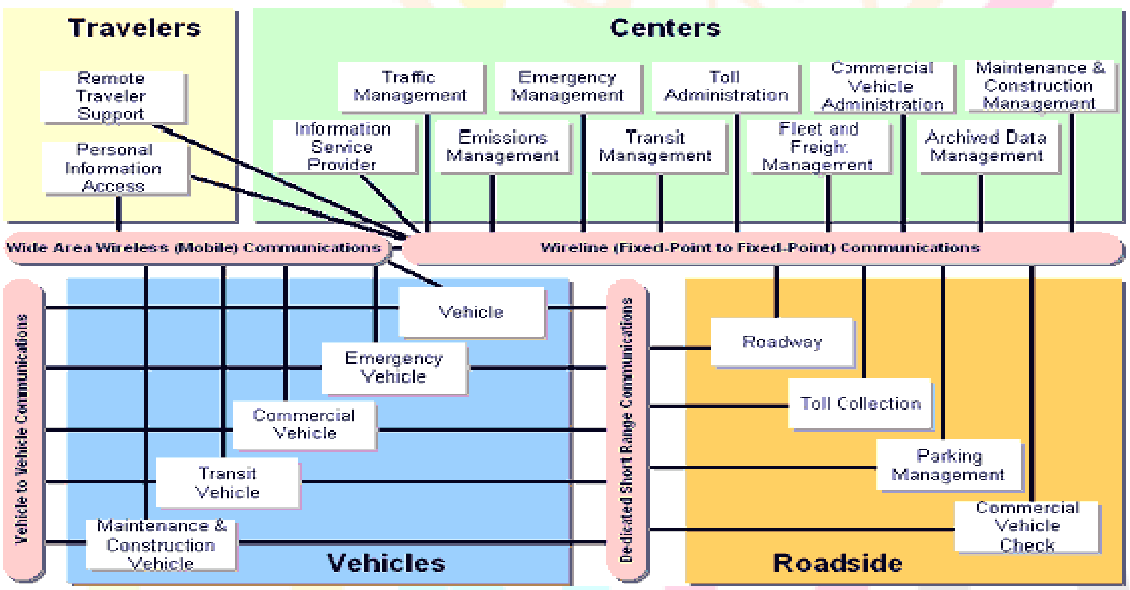


Figure 2: Broad Overview of ITS

A 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 guidanceinformation 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,

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 management in Japan [7

Meanwhile, the United States strove to formulate the Federal Transportation Bill, the successor to the PostInterstate 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, developan 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 fosterthe use of advanced technologies in surface transportation systems.

AIM

ITS can help transport planners to achieve policy objectives in many different ways. It can help to tackle congestion, pollution, poor accessibility and even social exclusion. It can also help to reduce journey times and improve reliability – either in actuality, or simply by changing people's perceptions. And it can improve the efficiency with which transport systems function. In certain circumstances – for example, parking guidance systems – it can help to supporteconomic and retail vitality.

When thinking about ITS it is vitally important to consider it, not as an end in itself, but as a means to achieve your (transport) policy objectives. It is possible that in some circumstances ITS may not be the best means of achieving transport policy objectives, but in other circumstances, it will. The trick is to select it for the latter situation, not the former.

SCOPE OF ITS IN INDIA

The ITS program in India is aimed at ensuring safe, affordable, quick, comfortable, reliable andsustainable 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 applicationswith traffic management centers in India

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

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 3: TRMS in Chennai

Automated Traffic Control (ATC)

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

Mumbai:

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 inthis 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 thevolume 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.

CHAPTER – 2

LITERATURE REVIEW

Sarkar, Sobhan, et al [5] explained the foremost objective of this study is to construct a method which could forecast the professional incidents (i.e., injury, property damage, and near-miss) with support vector machine (SVM) by employing a database containing nearly 5000 occupational accidents reports from an united steel plant consistent to the period of years 2010 to 2012.Parameter optimization of the SVM is achieved by grid search (GS), genetic algorithm (GA), and BAT algorithm to attain the healthier exactness of the classifier.

Bommes, Michael, et al [6] proposed the Video based detection systems, being a crucial part of intelligent traffic systems (ITS), display enormous possibilities as they do not only provide a stretchy way of data procurement but are also being established at a massive pace owing to current developments in hardware and software technology. With the intention to offer a healthier understanding on the approaches and possibilities of this technology, a structured review is offered which not only comprises current applications but similarly displays forthcoming use cases by examining the procedures of image processing and generalizing their outcomes to the forthcoming necessities of traffic engineering.

Wan, Nianfeng, Ardalan Vahidi, and Andre Luckow [7] introduced a Speed Advisory System (SAS) for pre-timed traffic signals is planned and the fuel minimal driving strategy is attained as a systematic solution to a fuel consumption minimization problem. The authors exhibited that the slight fuel driving strategy may go against intuition of some people; in that it substitutes between periods of maximum acceleration, engine shut down, and sometimes constant speed, known in optimal control as bang-singular-bang control. This paper assesses the impact of vehicles with SAS on the complete arterial traffic in micro-simulations.

Janušová, Lucia, and Silvia Čičmancová [8] pacts with status of dangerous transportation infrastructure and habits to guard it. Smart transportation classifications are innovative tools to advance and aid safety of dangerous infrastructure elements. The chief purpose is to describe smart transportation systems which could be employed to defend elements of critical road and rail transportation infrastructure.

Althoff, Matthias, and Robert Lösch [9] explained a frequently elevated dispute in contradiction of safely driving automated vehicles is that they would not blend well with traffic flow whimsically large progressions would request other traffic participants to cut in and thus put passengers of subsequent automated vehicles at risk. So as to test this hypothesis, we practice real data of thousands of vehicles documented in the United States as part of the Next Generation Simulation (NGSIM) program. To examine the hypothesis, we invented each human-driven vehicle is mechanized: These automated vehicles drive precisely as the documented human drivers, then they have a much smaller reaction time and therefore can still drive safely in circumstances that are insecure for human drivers.

Castro, Yuri, and Young Jin Kim [10] deployed three data mining classification methods to identify factors with the highest impact on car accidents. By comprehending the conditions in which the drivers and passengers are more probable to be killed or brutally injured in an automobile crash is of specific apprehension in traffic safety.

Al Najada, Hamzah, and Imad Mahgoub [11] designed a real-time Big Data system that obtains online streamed data from vehicles on the road along with real-time average speed data from vehicles detectors on the road side to (1) Deliver accurate Estimated Time of Arrival (ETA) by means of a Linear Regression (LR) model (2) Forecast accidents and blockings before they occur by Naive Bayes (NB) and Distributed Random Forest (DRF) classifiers (3) Update ETA if an accident or a congestion takes place by forecasting exact clearance time.

Park, Hyoshin, and Ali Haghani [12] described a modification of the boxplot is functional to capture segments at the extremity of the queue and at the head of the queue where subordinate occurrences might occur. The subsequent contour plot delivers temporal–spatial area under congestion to identify secondary incidents. The probability of categorized secondary incidents are chronologically forecasted from the point of incident response to the road clearance. The forecast recital of the ethical Bayesian learning method to neural networks outstrips the logistic method.

Walraven, Erwin, Matthijs TJ Spaan, and Bram Bakker [13] recommended an innovative technique to augment the traffic flow, built on fortification learning. The authors express that a traffic flow optimization problem can be articulated as a Markov Decision method. The author exploited Q-Learning to acquire strategies uttering the extreme driving speed that is acceptable on a highway, such that traffic congestion is condensed.

Vishnu, VC Maha, M. Rajalakshmi, and R. Nedunchezhian [14] explained over the traffic videos, the traffic video surveillance inevitably keyed out the vehicles like ambulance and trucks, which in turn supported us in guiding the vehicles at the time of emergency. Hybrid median filter has been exploited at the starting for pre-processing of traffic videos, and to eliminate the noise.Hybrid support vector machine (SVM with protracted Kalman filter) has been applied to hunt the vehicles. Next, the histogram of movement gradient structures is drew-out to categorize the vehicles.

García-Ródenas, Ricardo, María L. López-García, and María Teresa Sánchez-Rico [15] investigated about a prototype of an urban traffic control system created on a prediction-after classification approach. In an off-line stage, a source of traffic control approaches for a set of (dynamic) traffic patterns is created. The main objective is the k-means algorithm for everyday traffic pattern detection. The clustering method customs the speed, input attributes flow, and possession and it changes the dynamic traffic data at system level in a pseudo-covariance matrix, which accumulates the lively associations between the road links.

Yu, Bing, Haoteng Yin, and Zhanxing Zhu [16] projected a different deep learning technique, Spatio-Temporal Graph Convolutional Networks (STGCN), to challenge the time series prediction problem in traffic domain. As an alternative of spread on consistent convolutional and persistent units, we frame the problem on graphs and create the method with comprehensive convolutional structures, which permit much quicker training speed with less constraints.

Aslani, Mohammad, Mohammad Saadi Mesgari, and Marco Wiering [18] explained Reinforcement learning (RL) is an operative method in machine learning that has been pragmatic for scheming adaptive traffic signal controllers. One of the most competent and strong type of RL algorithms are incessant state actor-critic algorithms that have the benefit of fast learning and the skill to simplify the new and unseen traffic circumstances. These algorithms are employed in this research to enterprise adaptive traffic signal controllers named actor-critic adaptive traffic signal controllers (A-CATs controllers).

Yin, Jinghai, Jianfeng Hu, and Zhendong Mu [19] explained the primary objective of the authors are principally three: (i) A middleware architecture, illustrated as process unit (PU), which can connect with personal electroencephalography (EEG) node (PEN) and cloud server (CS). The PU receives EEG signals from PEN, identifies the exhaustion state of the driver, and transfer this data to CS. The CS refers the report messages to the immediate vehicles. (ii) An android application for fatigue detection is assembled. The application can be employed for the driver to sense the state of his/her fatigue based on EEG signals, and warn neighbourhood vehicles. (iii) The detection algorithm for driver fatigue is functional based on fuzzy entropy.

Iranitalab, Amirfarrokh, and Aemal Khattak [20] elucidated the multiple objectives like assessment of the performance of four statistical and machine learning methods including Nearest Neighbor Classification (NNC), Multinomial Logit (MNL), Random Forests (RF), and Support Vector Machines (SVM), in forecasting traffic accident severity; emerging a crash costs-based method for evaluation of crash severity prediction methods; and examining the effects of data collecting approaches encompassing K-means Clustering (KC) and Latent Class Clustering (LCC), on the recital of crash severity prediction approaches.

Navarro, Pedro, et al [21] proposed a mechanized sensor-based system to identify pedestrians in an independent vehicle application. Even though the vehicle is fortified with a comprehensive set of sensors, the paper highlights the processing of the data produced by a Velodyne HDL-64E LIDAR sensor. The effort narrates a comprehensive investigation of the concert of three dissimilar machine learning algorithms: k-Nearest Neighbours (kNN), Support Vector Machine (SVM)., and Naïve Bayes classifier (NBC).

Yao, Baozhen, et al [22] studied about a support vector machine model (single-step prediction model) composed of spatial and temporal constraints is projected. Moreover, a short-term traffic speed prediction method is enhanced by the single-step prediction technique.

Djuric, Nemanja, et al [23] initiated a deep learning-based method that takes into explanation of present state of the world and creates rasterized representations of each actor's vicinity. The raster pictures are formerly employed by deep convolutional models to deduce future drive of actors while accounting forintrinsic vagueness of the forecast task.

Mfenjou, Martin Luther, et al [27] presented the major objective of the research is, initially the complications of the operation of smart transport systems in emerging countries like sub-Saharan Africa. Furthermore, the researchers display a review of a road traffic method and an urban transport network model. To conclude, we suggest solutions, which deliver procedures for the exhibiting of a structure and detect traffic on inter-urban road transportnet works in emerging countries.

Yang, Chen, Shulin Lan, and Ming-Lang Tseng [29] recognized the persuading characteristics of synchronized expansion between metropolitan economy and logistics, and objects to disclose the reasonable associations among the numerous effect characteristics based on the decision-making trial and evaluation laboratory (DEMATEL) method. DEMATEL–Bayesian network model is employed to acquire the crucial effect attributes and driving path of the synchronized development.

Zou, Xin, Wen Long Yue, and Hai Le Vu [30] planned the method based on the envisaged investigation of MKD can be used to create a reference data and research basis for the application and growth of approaches in the field of road safety investigations. In specific, our outcomes display that the knowledge bases (classical documents) of road safety studies in the last two periods have engrossed on five major ranges of "Crash Frequency Data Analysis", "Driver Behavior Questionnaire", "Safety in Numbers for Walkers and Bicyclists", "Road Traffic Injury and Prevention", and "Driving Speed and Road Crashes".

CHAPTER - 3
METHODOLOGY

3.1 ITS IN 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 andsuch other needs. A few ITS applications have been introduced in India in metropolitan citieslike 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 applicationswith traffic management centers in India [56-58].

3.2 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 Indiancities are as follows

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 areupdated 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.

Chennai

FM radios

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

Delhi

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

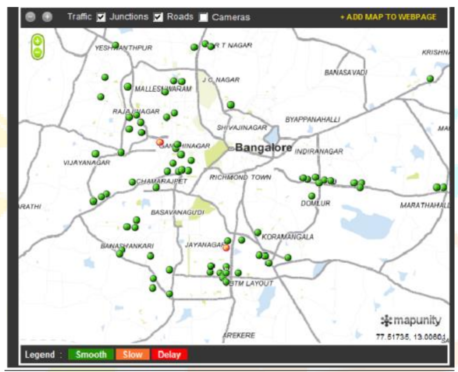


Figure 43: Real-time Traffic information available online [63]

<u>Advanced Public Transportation System APTS</u>

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 citiesselected for implementing BRT include Ahmedabad, Pune, Rajkot, Bhopal, Indore, Visakhapatnam, Vijaywada and Jaipur [65].

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. Thefunding for the project came from the Government of India under the Jawaharlal NehruNational Urban Renewal Mission.

Ahmedabad

Ahmedabad BRTS is a highly ambitious rapid transport system developed by Gujarat Infrastructure Development Board (GIDB), recognizing that no single mode would caterto the mobility needs of the city and that „Bus‟ forms the most critical segment of thepublic transport system in the Ahmadabad city. GIDB has thereby entrusted the systemdesign 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 someof 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 onDecember 3, 2009 [66].

CHAPTER – 4

DESIGNING REPORTS

4. DESIGNS & REPORTS

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 proposedon 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]

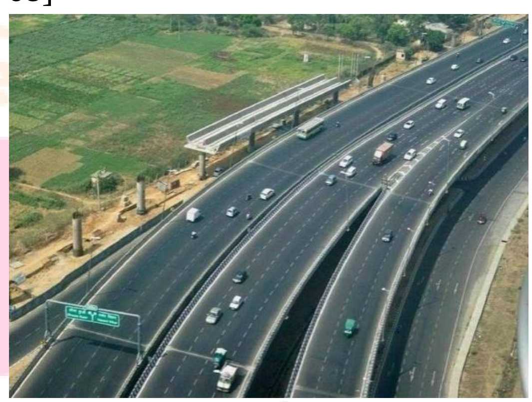
The following 8 routes will be covered in the Long-term Transportation

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 futureplans for smart cards

Figure 46: Toll Collection in India [69]

4.1 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 12.17percent. In 2007-08 alone, 9.6 million motorised vehicles were sold in India [71]. It is expectedthat 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 penetrationof ITS in Indian road scenario is relatively less and much more is needed to be done. To makethis 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 thedesign, implementation, lessons learned/best practices, and cost-benefit details
- Setting up fully functional Traffic Management Centres for coordinating the urban andregional 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 togenerate more interest and in turn

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 extractreal time data from video under the commonly seen heterogeneous/mixed traffic conditions isnot available making video also not a good data source for real time applications.

4.2 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 havebeen 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 thepublic 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.

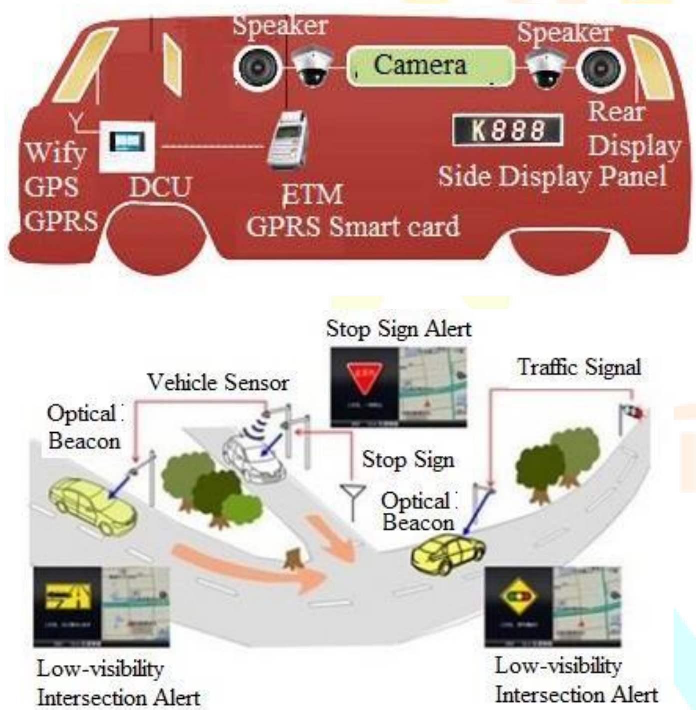
Some other cities around the world such as Singapore and London have introduced congestion charging schemes to reduce traffic. Such schemes ensure optimal usage of those specific roads, provide financial backup for road infrastructure maintenance and encourage the use of public transportation.

4.3 ITS TAXONOMY

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

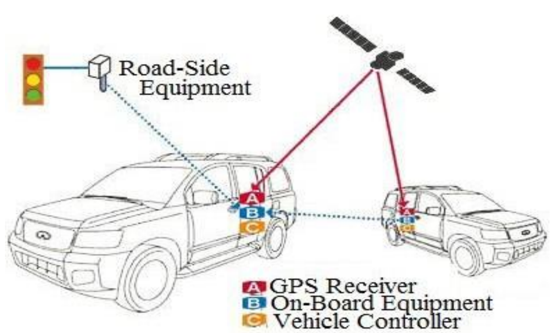
Vehicle Level

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 ofthe ITS is as follows [8]:

4.4 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 transportationnetwork. 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 autonomyin operations and decision-making is essential because of the heterogeneity of demand and performance characteristics of interacting subsystems.

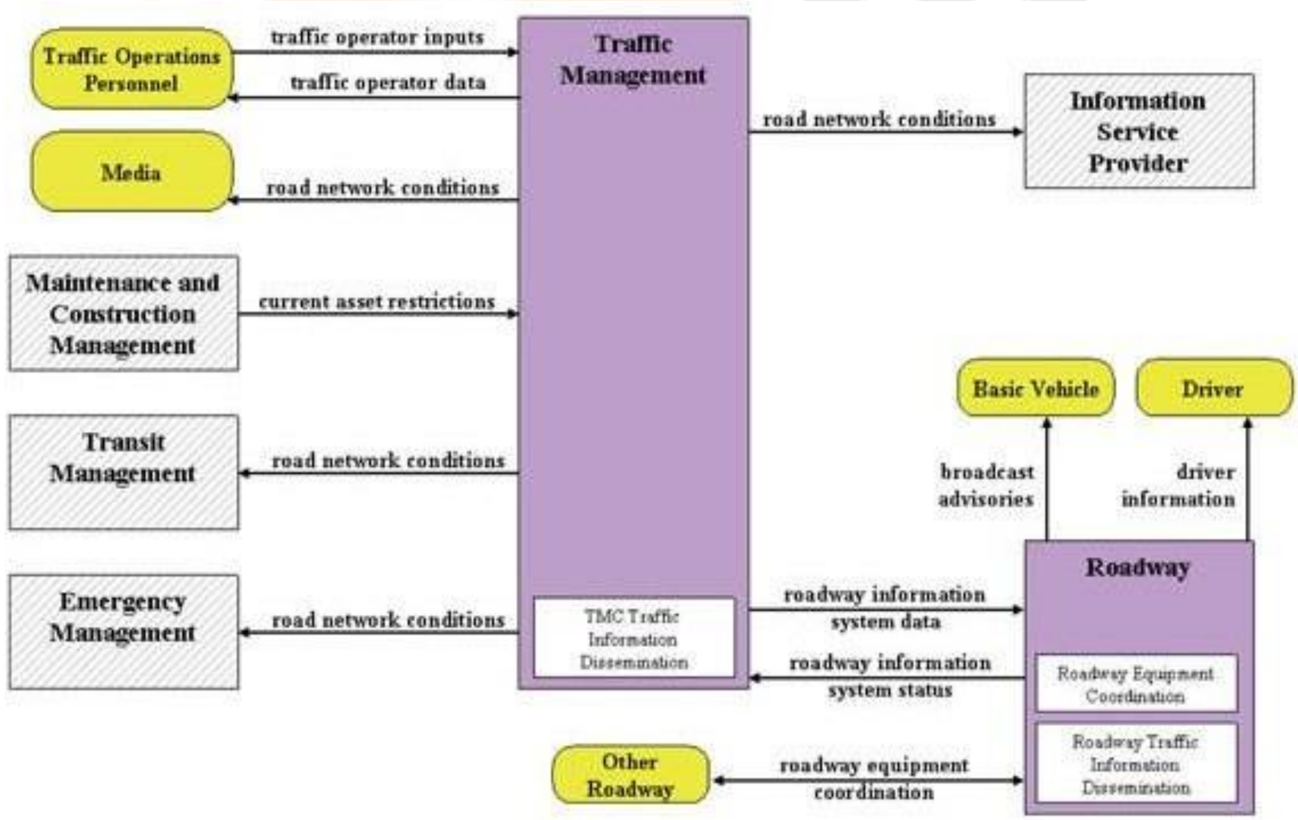


Figure 9: Schematic of the workings of a TMC [6]

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

4.5 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), GPSbased 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 50years. 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. Thethree main types of vehicle detectors used in current practice are inductive loop detectors magnetic detectors, and magnetometers.

The advantage of the above sensors/detectors is that, unlike technologies such as AVI, GPS etc., these areautonomous 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 forinstallation 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. Automatic Vehicle Identifiers (AVI) and Automatic Vehicle Locators (AVL)

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 tollcollection 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 datestamp 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.

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 requiresparticipation.

Figure 13: Smart card for vehicle identification [20]

Communication Tools

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.

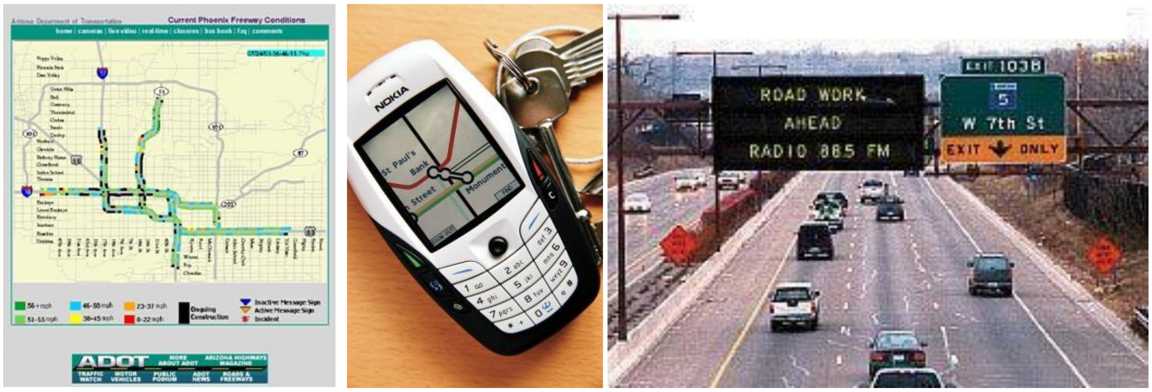
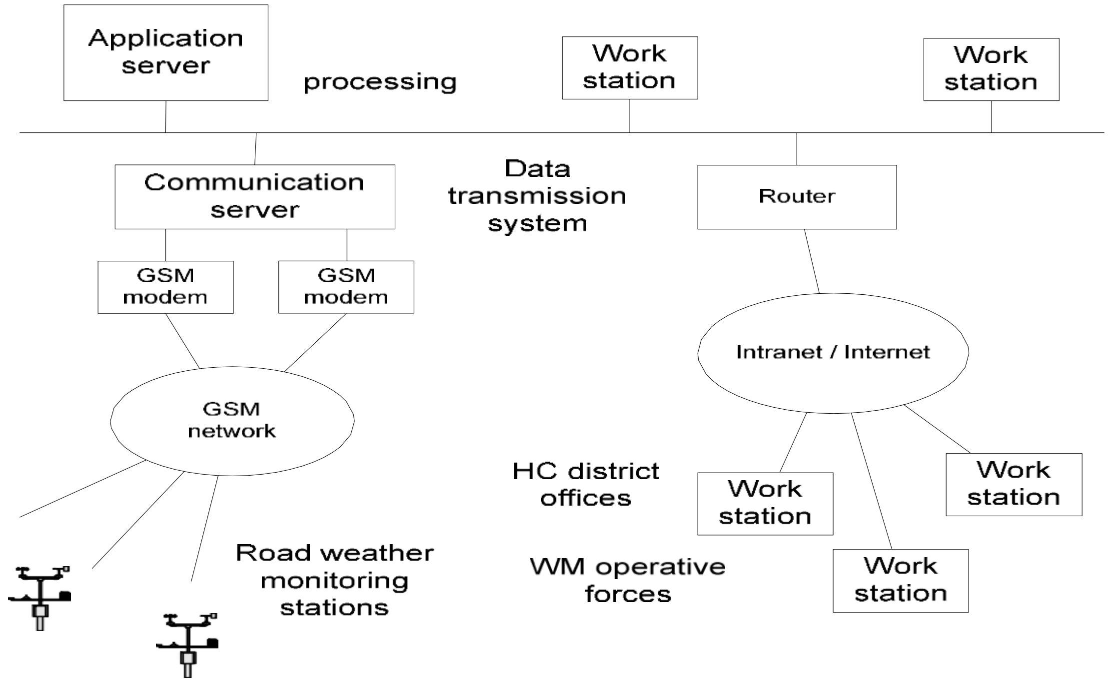


Figure 15: Tools of Travel Advice [Visualized from Ref. 23]

4.6 EFFECT OF TRAFFIC

The concern of affording the travel safety on the road network in the urban and suburban areas is one of the primary ethics which leads the engineering, traffic and transportation development. Approximately 3,500 people die by the road accidents all over the world every day. Tens of millions of people are wounded or disabled each year. Pedestrians, children, cyclists, bike, car users and the aged are amongst the most susceptible of road users. WHO functions with partners - governmental and nongovernmental - around the globe to elevate the report of the inevitability of road traffic injuries and support high-quality trainings associated to helmet and
seat-belt wearing, drunk and drive, rash riding and being noticeable in traffic
[2]. On the other hand, the accident is predictable, specified the definition, "an incident is distinct as the rapid accidental release of or the spotlight to a dangerous substance that marks in or might logically have brought about the injuries, deaths, considerable possessions or ecological harm, evacuation or sheltering in place
[3]. The expense of these accidents can be serious trouble to the government. Therefore, the road accidents are a severe threat to public transportation. In particular, the colossal economic toll of road accidents on human societies inflict, recuperating road safety needs awareness to three effective features: human, the road and the vehicle
[4]. The bureaucrats of the transport system also require stabling the road safety wants through inadequate resources to lessen the accidents and augment the road conditions. In fact, the primary objective is as conceivable in reducing accidents that can be loomed to this target by managing the traffic engineering, driver training and implementation.



4.7 Access control, Rome .,

Technology

Rome adopted in 1994 the access limitation to the LTZ of the city centre sectors east of Tiber (area of 4.6km2). In 1998, the payment for a yearly permit to access the area only for specific users was introduced. In October 2001, during the PRoGR€SS demonstration, the electronic full scale Access Control System and flat-fare Road Pricing scheme (ACS+RP) called IRIDE was switched on with the use of 23 entrance gates and a complex control centre located in STA. The automation of the access control system is accomplished through the use of a series of gates that can effectuate, without user intervention, the identification and/or the applicable tariff for vehicle entrance into the restricted area (vehicle-ground beacon). The enforcement is active during the weekdays from 6.30am to 6.00pm and on Saturday from 2.00 to 6.00pm.

The following types of technology infrastructure, based on the technology used for the TELEPASS system:

- TV Camera and infra-red Illuminators
- Microwave Transponder
- On-board Unit with Smart Card

Scale

• Full real pricing scheme-real charging, real users, real revenues

• Area covered by system: 4.6km2

• Number of charging points: 22+1 entrance gates

• Number of users: 30,000 resident vehicles, 30,000 service vehicles (free access), 50,000 plates for disabled peoples (free access), 29,000 authorised individuals and 8,000 freight delivery vehicles (have to pay for access)

• Number of trips per day: about 70,000." The effect of the scheme was to lead to a 10% decrease in traffic during the day, a 20% decrease in traffic during the restriction period, a 15% decrease in the morning peak hour (8.30-9.30), 10% increase of two wheels and a 6% increase in public transport use. Full details of the scheme, apart from the cost of its implementation, are available at http://www.progressproject.org/ and then by going to Project Reports and downloading Deliverable 5.2. More up-to-date information, in Italian, is available at http://www.atac.roma.it/ and then by following the link to "Permessi centro storico - ZTL".

4.8Road pricing, Stockholm

You can refer to http://www.stockholmsforsoket.se/templates/page.aspx?id=2453 for information on the Congestion Charge Trials which were implemented for Inner Stockholm on 3/01/06 and will end on 31/7/06, after which (on 17/09/06) a referendum will be held to ask citizens whether they wish the trials to become permanent. The scheme has cost around €350 million to implement, funded entirely by the Swedish national government.

Vehicles passing any one of 18 points at the boundary of Stockholm city centre (inbound or outbound) have their numberplates photographed during scheme operating hours (0630-1829, Monday to Friday). The charge varies by time of day between €1 and €2 per pass (maximum payment €6 per vehicle per day). If the driver does not pay the relevant charge within five days, they receive a reminder and administrative charge of around €7 Euros. If another 4 weeks elapses, they are fined €50.

ITS comes into play because the easiest way to pay is via a transponder, fitted to the car, which communicates with the gantries at the charging points. The vehicle owner then pays the charges by direct debit. There is a video about installing transponder at the webpage shown above. The scheme has reduced traffic levels within the cordon by about 25% compared with the same period in 2005.

4.9 MULTIMODAL TRIP PLANNING

Thanks to the EU IST project TRANS-3 and the earlier CAPITALS PLUS project, a multimodal trip planning website http://www.transbale.com/index.php was set up and ran for the duration of the project, to 2002. The website is still active although the journey planning element is not, as funding was not continued. Some 64% of the total project budget of €940,000 was spent on the development of the website and journey planner.

The transport policy objective of the partners has been to achieve a shift from the individual car to the alternative modes. The solution proposed by Transbasel is centred on a multi- and inter-modal journey planner. The journey planner proposes a choice of trips with different modes in response to each request… It intends to demonstrate to a habitual car driver hat public transport, bicycle, Park and Ride are often comparably fast and sometimes faster than the car. A second mouse click leads to the necessary details for the proposed trips.

The journey planner covers a diameter of 30 km: the agglomeration and its surroundings. The goal is to cover the trips which are part of daily life of the residents, and which have their origin or destination or both within the agglomeration. The information is based on a superposition of static data… public transport timetables, and real time data. The latter are available for car park occupancies and dynamic road travel times on certain links. The journey planner is embedded in a website."

Transbasel was evaluated by a variety of means, but the largest evaluation involved a sample of only 88 users who completed a pop-up questionnaire on the website. Of these, 83% did not change their behaviour as a result of the information, 7% changed route, 6% changed travel time and 4% changed mode. These results are indicative only due to the small sample size.

4.10 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 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,

CHAPTER – 5
DATA ANALYSIS

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.

5.1 MACHINE LEARNING AND BIG DATA ANALYTICS

Machine learning is an assortment of techniques that allow computers to systematize data-driven method building and programming over a methodical detection of statistically substantial patterns in the existing data. Machine learning techniques can be categorized through the type of "learning." There occur numerous elementary forms of learning techniques, such as:

1.Supervised learning where formerly categorized data is employed to assist the learning process; (ex. Classification, Regression)

2.Unsupervised learning, where only unlabelled data is deployed; (ex. Clustering, Association)

3.Semi-supervised learning, which customs both labelled and unlabelled data

4.Reinforcement learning, where the learning process is directed by a sequence of response / reward cycles. The enhancement of big data and the Internet of things (IoT) is quickly advancing and moving all fields of technologies and industries by swelling the profits for administrations and individuals. The evolution of data formed via IoT has performed a pivotal role on the field of big data. IoT provides a point for radars and devices to communicate flawlessly in a keen setting and empowers data distribution across all platforms in an appropriate way. IT has perceived its fresh implementation in smart cities with attention

5.2SOLUTION FOR ISSUES AND CHALLENGES OF ITS IN INDIA

There is a perception in some circles that public transport is “green”, sustainable and environmentally friendly, and that cars and trucks are the opposite, so there are moves to get drivers out of their cars, and to transfer freight from road to rail. The reality is much more complex; public transport vehicles, which are typically older, may emit more pollutants than private cars; and if they travel empty or nearly so, they are less ecient than even a single-occupancy vehicle. Typically the road network carries ten times the people and ten times the freight that rail does, so a small transfer from road may cause overload on what is often a rail network running at capacity. And public transport operates best in high-density urban environments, and less well in suburban areas or sparsely populated rural environments. Nonetheless, public transport is crucially important, especially in urban and suburban areas – and the world-wide trend is towards increasing urbanisation. By 2020, 80% of Europeans will be living in urban areas; in some countries the proportion will be 90% or more. Another trend is the use of mobile technology. It is normally assumed that commuters want to minimise their travel time—and are willing to pay for the privilege. But with tablets, laptops and smart phones, travel time can be used productively, unlike in a car; this undoubtedly makes some commuters to choose transit rather than car—even if the journey takes longer – a trend that MNOs would do well to encourage. A journey may include more than one mode of transport. Research identifies four areas that can make public transport easier and more convenient (DfT 2014): Improving the quality and availability of information; Smart and integrated ticketing; Improved and reliable connections in multi-modal journeys; Safe, comfortable and easily accessible transport facilities, meeting the needs of passengers. An important part of this is making data available for app and other developers; see www.data.gov.uk - and case studies below. 7.1 Bus, Metro, Train As the GSMA (2012) White Paper: "Mobile NFC in Transport" indicated, Near Field Communication (NFC) is a contactless radio technology that can transmit data between two adjacent devices. Mobile phones are increasingly being equipped with NFC capabilities, enabling new digital services that could greatly improve the passenger experience of public transport. The combination of NFC with mobile connectivity enables many benefits in the transport sector, including: Enhanced value and functionality of existing contactless infrastructure; Greater passenger convenience - ability to buy NFC tickets via a mobile connection and avoid queuing;

1. Lower sales and distribution costs, fewer plastic cards, paper tickets and their associated physical infrastructure, and concomitant environmental benefits; Fast, accurate and transparent ticket validation; 2.
2. More flexible and interoperable ticket systems - NFC handsets can support multiple ticketing standards, creating a seamless passenger experience; Personalised communication with passengers and promotion of public transport. This could pave the way for complete, integrated solutions covering diaerent modes of transport. Intelligent Transportation Systems Report for Mobile 55 7.3.
3. Public Transport Image by permission of the Swedish Transport Agency. The dotted line shows the scheme boundary, the red dots are the locations of the charging stations.
4. No congestion tax for journeys on Essingeleden Public Transport 56 Potential benefits of mobile NFC for mobile operators include: Greater usage of mobile services - NFC interactions can prompt more usage of the mobile network; Spur adoption of mobile NFC and accelerate upgrade of handsets and UICCs; A platform for mobile commerce services, such as targeted advertising. Three years later, these predictions are coming to pass. Transit agencies are adopting new payment options for travelers including mobile ticketing
5. According to Juniper Research, mobile ticketing across all forms of transit will triple between 2013 and 2018; one in eight North American smart phone users are expected to use it as a public transport ticket by 2016.Transit fares are typically low-value; handling cash is expensive, and prone to fraud and theft, as well as potentially delaying transport services.
6. Mobile technologies minimise these risks; passengers can use smart phones to buy their ticket

or pass anytime, anywhere, minimising boarding delay and improving the passenger experience.

7. For public transit operators the benefits include increased ridership; cost reductions and better management of their operations, especially with integrated ticketing of diferent transit modes. A Smart Ticketing Alliance was set up in Brussels n 2014 to work towards a single transport specification for NFC phones across Europe facilitating the implementation and deployment of NFC-enabled devices.

8. 7.1.1 Dubai In 2013 Dubai became the first city in the Middle East to allow mobile phones to access public transport (GSMA (2014d). The "Smart Nol" service ("Nol" means "fare" in Arabic) enables a passenger to open a ticket barrier by tapping their handset against a reader. The NFC technology connects to the handset to validate the passenger's virtual Nol account, stored on the SIM card.

The "Smart No l" service was developed by Dubai's Roads and Transport Authority (RTA) and the Emirate's mobile operators Etisalat and Du. Removing the need for a separate physical card, of which there are six million in use in Dubai, will reduce the RTA's costs and environmental impact. The service also reinforces the high-tech, forward-looking image of Dubai's public transport, thereby increasing patronage. Passengers can review their Nol usage on their handset at anytime, anywhere, rather than having to use a machine in a metro station. They can use an Etisalat or Du app (Figure 9), or a special SIM toolkit menu, to check their current balance, the amount and date of their last balance recharge, the date and cost of their most recent journey, whether they have reached the daily fare cap, and their tag ID and expiry date, which they need to contact the RTA call centre. Passengers need a NFC handset and NFC SIM card to use the Smart Nol service.

■ Smart Nol can be managed using Du's Android-based transport app. It can also recharge their Salik road toll account, find the closest metro station, book a taxi and pay for parking.

■ Etisalat's NFC Android appcan access the Nol card, view credit and check transaction history.

5.3 Dallas Area Rapid Transit (DART)

After investigating contactless smart cards and credit/debit cards, DART opted for mobile ticketing in its Texas-based public transit services, as its customers increasingly used smartphones, including ones with NFC. Mobile ticketing gives benefits of reduced capital costs (less need for ticket vending machines), flexibility for the future, new payment options and convenience for customers. DART's mobile ticketing app, GoPass, allows flexible ticket validation, including screen animations and ultimately NFC. Several types of payment are available including bank cards and Pay Pal. Mobile ticketing has advantages for customers; the app includes a trip planner, disruption alerts, and estimated times of arrival for buses and trains. An SMS text service alerts travellers to the next scheduled bus or train service at their stop. GoPass also has a link to buy a ticket in advance, and people feel safer because they don't have to get out their wallet at a ticket o‰ce. DART also operate a car-pooling service and has partnered with the Zipcar car-sharing organisation

5.4 JUST RIDE IN ATHENS

Transport for Athens and Masabi, a UK-based transit mobile ticketing organisation, announced in January 2015 the deployment of a mobile ticketing scheme, JustRide, for public transit in the city, following a pilot in December. This digital ticketing system supplements the existing paper ticket and cash-based operation; it has previously been deployed in Boston, London, San Diego and shortly New York. Customers can conveniently buy and display tickets for immediate or future travel using their smartphone. Transport for Athens will experience reduced costs of handling cash and printing paper tickets.

5.5 OTHER SMART-TICKETING OPERATIONS

Maryland Transit Administration (MTA) "My MTA Tracker for Bus", enables customers to determine the estimated arrival time of their Local Bus via computer, tablet, smartphone and standard phone. Users can receive SMS or email alerts for their particular route. Following in the footsteps of several other US cities, the San Francisco Municipal Transportation Agency (SFMTA) is piloting a scheme to allow transit users to buy tickets using their smartphones. It may scale down other fare collection mechanisms if mobile payments prove popular and cost-eªective

6.6 MATATUS – NAIROBI

Nairobi commuters can now access the routes of over 20,000 matatus (public buses) – see Figure 10) in the city, using the "Transit App" developed by the University of Nairobi, Columbia University's Center for Sustainable Urban Development, Groupshot, and MIT's Civic Design Lab in a collaborative research project called "Digital Matatus". As well as a trip planner the app includes bus schedules, stops and routes, so a network connection is not essential. Real-time updates on bus movements or routes are not currently available but may be added later. To get the data, volunteers with GPS-tracking cellphones travelled on the matatus, compiling a list of routes, arrival times, and stop locations – which turned out to be surprisingly coherent and logical (Figure 11). They then converted the data into GTFS (Google's General Transit Feed Specification - a standard format for public transport schedules and related geographic information). The Transit App developers say they are confident the methodology can be applied to any informal transit system worldwide. The app can be downloaded from the App

6.7 CAR SHARING AND CAR CLUBS

Car-pooling and car sharing began in the late 20th century, as a mechanism for Travel Demand Management (TDM) to reduce congestion and environmental damage. They also gave cost and time savings, especially for commuters. They could be formal – managed and encouraged by an employer – or informal amongst family and friends. A car club provides its members with flexible access to the hire of vehicles, which are parked in reserved spaces, close to homes or workplaces and used on an hourly, daily or weekly basis (DfT 2005). In some places, particularly the US, High Occupancy Vehicle (HOV) lanes (section 7.2.3) were built on freeways, usable only by multi-occupancy vehicles, in order to encourage car-pooling – though vehicles were often multi-occupancy for other reasons, such as a family going on holiday. They also gave rise to the curiously named practice of "slugging", where people "hitching" lifts would queue at certain points, particularly in the vicinity of 3+ HOV lanes (at least 3 people in the vehicle); it was in drivers' interests to pick them up because 3+ car-pools were more di‰cult to create and maintain. Dynamic ridesharing was a subsequent development, again particularly in the US, encouraged by technology and social networking – minimising the "management overhead" of formal carpools. Commuters decide to drive or take the bus, depending on how flexible they need to be and whether the bus is running on time. If they drive they can pick up riders anywhere along a route; potential riders can contact drivers through smart phones and GPS information. Riders may make micro-payments to drivers, who also gain by using HOV lanes.

6 DETAILS AND ANALYSIS OF UPCOMING TECHNOLOGIES

6.1 SMART CITIES

A smart city uses intelligent technology to sustainably enhance the quality of life in urban environments, saving money, minimising waste, measuring domestic water usage and managing transport routes, the latter being relevant here. ICT links and strengthens networks of people, businesses, infrastructures, resources, energy and spaces, as well as providing intelligent organisational and governance tools. According to the "Guide to Smart Cities: The Opportunity for Mobile Operators" (GSMA 2013a), the global mobile addressable market in smart cities, transport, utilities and intelligent buildings will amount to USD67.1bn in 2020, up from USD22.8bn in 2012, according to Machina Research. By 2020, security in intelligent buildings, (which includes connected security alarm systems, fire alarms, CCTVs, intercoms and building access control) will account for 52% of the total addressable market for mobile operators. Smart meters will be the second largest addressable revenue category, with 22% of the total, followed by environment and public safety sector applications with 14% in 2020. These figures exclude the potentially significant revenues that mobile operators could earn from the data generated by smart city services. Other commentators project the smart cities industry to be worth more than $400 billion globally by 2020. Mobile operators are already involved in smart city projects. Of the 150 smart cities the GSMA tracks, more than 100 have deployed services (beyond smartphone apps) that use mobile networks. The GSMA has identified 232 mobile products and services that cover a variety of smart city sectors, of which transport accounts for 99 worldwide, such as ticketing applications, intelligent transport systems and tra‰c information. Deutsche Telekom is rolling out services developed in its test-bed in Friedrichshafen to other German cities. The Amsterdam Smart City project aims to turn the city into the smartest in the world. Initiated by the city, its Economic Board, and KPN Telecom amongst others, it now has over 70 partners. The suburb of IJburg has become a "Living Laboratory" with free Wi-Fi and a new optical fiber network. One partner, Tra‰cLink, is developing "The Digital Road Authority" to shorten the response time of emergency services by controlling tra‰c lights and bridges. It also provides IJburg residents with personalised travel advice, and reduces emissions by guiding trucks to available unloading zones. http://amsterdamsmartcity.com/about-asc £50 million over 5 years has been earmarked by "Innovate UK" for the new Future Cities Catapult centre established in London and the Future Cities Demonstrator Project in Glasgow.

The UK DfT is working with the nine largest English cities outside London through the Smart Cities Partnerships to support them in delivering smart, integrated ticketing schemes; the principal bus operators have committed to deliver smart multi-operator tickets in 2015 (DfT 2014). The Borough of Greenwich (London) Smart City is a test site for one of the UK's Driverless Cars project (section 3.2.3). Intelligent Transportation Systems Report for Mobile 71 9. Smart cities and the Internet of Things (IOT) Smart cities and the Internet of Things (IOT) 72 In Singapore, the Land Transport Authority's mytransport.sg portal has prompted the creation of 23 mobile apps since it was set up in 2010. NCS, the IT arm of SingTel, and its partners have an Urban Mobility initiative using advanced technologies to improve urban mobility. The Indian government has announced a plan to build pollution-free smart cities at each at the country's 12 major ports, including Mumbai and Chennai, by 2020, starting in 2015. They will be built to international standards and use green energy: bio fuels, solar energy and wind power. According to GSMA (2013a), mobile operators can play a role in four key elements of smart city services:

■ Connectivity: connecting city infrastructure and individuals' handsets to central servers and databases;

■ Data aggregation/analysis: combining data from multiple sources to produce new insights;

■ Service delivery: delivering real-time information to people and machines that will enable them to adapt and respond to events in the city;

■ Customer interface - providing customer support operations, such as call centers and web portals, as well as delivering messages to subscribers.

6 .2 M2M AND THE INTERNET OF THINGS

The Internet is evolving from connecting people to connecting things – the so-called "Internet of Things" (IoT), enabled by Machine to Machine (M2M) communication.By 2020, handsets will constitute only 72% of cellular connections, from 92% in 2014, with an estimated 14.5 Billion connected M2M devices (GSMA 2014e). In his Keynote Speech at the 2015 Consumer Electronics Show (CES) in Las Vegas, the Samsung Electronics CEO said that the IoT represented the most promising of all markets in the technology industry. Samsung believes that openness is key to IoT development, as is collaboration between the technology industry and the industries that IoT will revolutionise. By 2017, all Samsung televisions, and by 2020 all Samsung hardware, will be IoT devices. The connected car (3.2.1) is one instantiation of the IoT. Also at CES 2015, the Ford CEO indicated that the company plans to become a transportation data analytics organisation, absorbing data from cars and people and turning it into a business, related to vehicle quality, insurance costs, car sharing, driving patterns, parking apps, transportation analysis and societal problems – not just smarter cars, but smarter roads and smarter cities. Ford sees data as a major asset.

6.3 THE EMBEDDED UNIVERSAL INTEGRATED CIRCUIT CARD

So a new type of mobile network user will emerge; automobile, consumer electronics, energy companies and others will see their devices used by millions world-wide. M2M communication will become standard, primarily using mobile networks. However, there is an issue with the SIM card in these M2M applications. One of the benefits of the SIM is that customers can easily change the SIM and network operator if they wish. But for M2M applications a change of SIM is impractical for a number of reasons; it may be inaccessible, or soldered in to prevent fraud and damage from vibrations. Operators recognised this and developed "GSMA Embedded SIM" technology to allow change of operator, subject to any contractual conditions, if required.

The eUICC is an embedded SIM. The GSMA has produced an embedded SIM Specification to accelerate growth in M2M (GSMA 2014e). The specification provides a standard mechanism for remote management of M2M connections, allowing "over the air" provisioning of an initial operator subscription, and a change to other operators subsequently, while maintaining the same level of security as with traditional removable SIMs. shows the eUICC Subscription Manager architecture. Operators use the Data Preparation entity to securely encrypt their operator credentials for over the air installation within the SIM. The Secure Routing entity delivers the encrypted operator credentials to the SIM and remotely manages the SIM thereafter to enable, disable and delete the credentials as necessary during the product's lifetime. Use of the eUICC could minimise some of the security problems outlined in section.

CHAPTER – 6

CONCLUSION

6.1 GENERAL RECOMMENDATIONS

A good way of keeping up-to-date with the ITS field is attending and exhibiting at ITS conferences. The annual ITS World Congress Conference and Exhibition rotates between ITS and Intelligent Vehicle conferences in the US. Standards are crucial; MNOs and the cellular industry have extensive standards experience and should be involved in ITS standards development, such as

C-ITS in Europe. Interoperability is crucial – GSM is a good model for ITS in general and tolling in particular. National and multi-national collaborative R&D programmes

The Smart City arena, Vodafone Global Enterprise and AT&T have partnered with IBM, and KT with Cisco. Clearly, the MNO must ensure that such partnerships allow it to capture significant value.

■ Alternatively a mobile operator can partner with a systems integrator within the same telecoms group as do Deutsche Telekom (with T-Systems) and Telefonica (with Telefonica Digital).

■ Another option is to acquire an ITS-aware organisation, or buy a stake in one; Verizon bought Hughes Telematics .

■ The ITS field is changing rapidly, largely because of mobile communications, which are of intrinsic importance in the field. Users will also pay for real-time data on trafic flows and incident detection, useful for transport planning as well as for trafic information broadcasting.

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