Intelligent Transportation Systems (ITS): A Technology Solution
For 21st Century Public Transport System Management

By

Dr. V. Trinadha Rao \(^1\), Alok Bhardwaj \(^2\) and Ch.V. Subba Rao \(^3\)

Abstract

Intelligent Transportation Systems (ITS) are identified as the means to achieve sustainable and environmental friendly transportation for the 21st Century. Advanced information and communication technologies are required for ITS. These include Data Storage & Processing Equipment, Wireline & Wireless Communication Systems, Global Positioning Systems (GPS), Sensors, Smart Cards etc. In addition to the above technologies, institutional and market factors play an important role in successful ITS deployment. ITS application functionality includes collection and processing of real-time data, generating and utilizing information for various purposes such as controlling and managing traffic, handling fleet operations (public transport and private carriers), emergency management and assisting users in their travel related decisions. The benefits of ITS includes Reduction of traffic congestion, Enhanced safety, Mitigation of environmental impacts of transportation systems, enhanced energy performance, and improved productivity.

Many governments are appreciating the benefits of ITS and deploying them in their regions. As a first step, National ITS architectures were designed by the respective nations, to provide overall guidance to ensure deployment strategy, systems compatibility and interoperability. ITS architecture defines user services, physical subsystems, information flows between subsystems, and communication requirements for deploying ITS applications. As many new technologies arise, ITS technologies are undergoing an evolutionary process. This presents the greatest challenges of deploying ITS systems integration. Challenges presented by ITS deployment include standardization, addressing security and privacy concerns, institutional and inter-agency barriers, availability of funding, public-private partnership. ITS technologies are user service centric and have been driving ITS development across the world.

The present study attempts to consolidate different ITS technologies and classify them as Sensing, Communication, Information and Control technologies. Automatic Vehicle location and Fleet Management Systems are taken as a case for strategic enterprise management of Advanced Public Transportation through information technologies.

\(^1\) Associate Consultant, TATA Consultancy Services (TCS), Mumbai, India 400 066
\(^2\) Senior Consultant, TATA Consultancy Services (TCS), Mumbai, India 400 066
\(^3\) Assistant System Engineer, TATA Consultancy Services (TCS), Mumbai, India 400 066
1. Introduction

Technology has been driving the developments in the realm of transportation from the times of Industrial Revolution to the present day Digital Revolution. Until the 20th century, technology in transportation was focussed on two objectives – (i) meeting the demand of faster mobility by different modes and (ii) building capacity and expanding network facilities to accommodate growing traffic needs. The constraint on the available space, growing vehicle population and number of trips led to severe traffic congestion, resulting in environmental degradation. In 2000 alone, traffic congestion cost motorists a staggering $67.5 billion in wasted time in 75 large urban areas of USA. This situation has resulted in innovative shift of infrastructure management through advanced technologies, to ensure efficient and environment friendly user services. Development of vehicle detection and information technologies on top of communication technologies has offered ways to collect the real-time traffic data for processing at a central facility. Processed information is used for various management purposes such as control, traveler information, incident detection and response. ITS have thus addressed the need for working towards regionally integrated transportation systems.

2. Major ITS Functional Areas

The major ITS application areas can be classified into the following functional groups:
- Advanced Public Transport Systems (APTS)
- Advanced Traffic Management Systems (ATMS)
- Advanced Traveler Information Systems (ATIS)
- Electronic Toll Collection and Traffic Management (ETTM)
- Commercial vehicle Operations (CVO)

Figure 1 illustrates basic ITS activities like Data Collection, Processing (Data Computing), Communication and Information Utilization. In all these activities, technology plays a vital role for 21st Century Surface Transportation Demand Management.

Figure 1: Categorization of ITS Activities
Figure 2: ITS Technology Classification in major categories

**SENSING/SURVEILLANCE**
- **ROAD BASED**
  - Passive
  - Active
  - Microwave
  - Infrared
  - Laser
  - CCTV
  - Signpost
- **VEHICLE BASED**
  - Inductive Loop Detectors
  - Magnetometer
  - Piezo-electric Detectors
  - Pneumatic Tubes

**COMMUNICATION**
- **DATA VOICE VIDEO**
  - Wire Line
  - Wire Less
  - Wide Area Short
  - FDDI ISDN
  - Ethernet
  - SONET ATM
  - Fiber Optics
  - GSM ESMR
  - SMR PCS
  - DSRC CDPD
  - PCS TAL

**INFORMATION TECHNOLOGIES**
- **SOFT TECH**
  - WEB
  - GIS
  - CAD
- **HARD TECH**
  - Electronic Payment
  - Incident Detection Verification
- **INCIDENT DETECTION**
  - Pattern Recognition
  - Time Series
  - McMaster
  - KBES
- **DATA FUSION**
  - Data Association
  - Figure of Merit
  - Gating
  - Kalman Filters
  - DSER
  - ANN
  - AI-Expert Systems
- **TRANSPORTATION CONTROL/ENFORCEMENT**
  - Closed Loop
  - Adaptive Signal Control
  - Signal Priority
  - Image Processing
  - SCOOT
  - SCATS
  - License Plate Recognition

**ITS Technologies** Transportation Industry Practice-TCS
ITS technologies can be categorized as:

- Sensing and Surveillance Technologies
- Information Technologies
- Communication Technologies
- Traffic Control Technologies

Technology classification in each of the above categories showed in figure 2. These technologies are assisting public and private agencies across the globe to meet increasing demands on the surface transportation system. In this study an attempt has made to illustrate the application of APTS technologies in Road Transport Corporation (RTC) Management.

3. RTC Management – APTS Technologies

APTS technologies are a collection of technologies that increase the efficiency and safety of public transportation systems and offer users greater access to information on system operations. The implementation of APTS technologies is transforming the way public transportation systems operate, and changing the nature of the transportation services that can be offered by public transportation systems. The goal is to provide public transportation decision-makers more information to make effective decisions on systems and operations and to increase traveler’s convenience and ridership.

APTS technologies can be organized into three broad categories that describe the technologies relevance to transit applications. Each category is comprised of a variety of technology choices that are available to help transport agencies and organizations meet traveler’s service needs while increasing safety and efficiency. The three APTS technology categories are:

A. Fleet Management Systems (FMS)

- Communication Systems
- Automatic Vehicle Location Systems
- Transit Operations Software
- Geographic Information Systems

B. Traveler Information Systems (TIS)

- Pre-Trip Transit and Multimodal Traveler Information Systems
- In-Terminal/Wayside Transit Information Systems
- In-Vehicle Transit Information Systems

C. Electronic Payment Systems (EPS)

- Smart Cards
- Fare Distribution Systems
- Clearinghouse
Table 1 presents the projected minimum, most likely and maximum benefits (in discounted, year-2000 dollars) for fleet management system deployments that are currently operational, under implementation and planned for deployment in USA.

Table 1. Fleet Management System Benefits (in Millions of discounted Y2000 dollars)

<table>
<thead>
<tr>
<th># Deployments</th>
<th>Minimum Estimate</th>
<th>Most Likely Estimate</th>
<th>Maximum Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational</td>
<td>$557.2</td>
<td>$821.5</td>
<td>$1,089.5</td>
</tr>
<tr>
<td>Implementation</td>
<td>$153.9</td>
<td>$226.1</td>
<td>$301.9</td>
</tr>
<tr>
<td>Planned</td>
<td>$99.7</td>
<td>$146.9</td>
<td>$200.5</td>
</tr>
<tr>
<td>Total</td>
<td>$810.8</td>
<td>$1,194.5</td>
<td>$1,591.9</td>
</tr>
</tbody>
</table>

3.1 COMMUNICATIONS SYSTEMS

Effective and efficient operation of transit systems relies on a communications infrastructure and vehicle-based communications technologies. Communications systems are used to transmit voice and data (both raw and processed) between transit vehicles and operations (e.g., dispatch) centers, and to transmit commands between operators and technologies (e.g., signal priority commands to traffic signal systems). Transit communications systems are comprised mostly of wireless technologies and applications. The two-way voice radio system used for fleet management and vehicle dispatching remains at the heart of most transit operations. However, other communication technologies are becoming common; for example, short-range data links for traffic signal priority. Mobile voice and data communication systems for bus transit include the use of analog, digital, and cellular digital packet data (CDPD).

3.2 AUTOMATIC VEHICLE LOCATION (AVL) SYSTEMS

AVL systems are computer-based vehicle tracking systems that function by measuring the real-time position of each vehicle and relaying the information back to a central location. They are used most frequently to identify the location coordinates of vehicles in order to better satisfy demand. They also serve to provide location coordinates to respond to emergency situations. The location technologies found on AVL systems are usually one of the following, but can also be used in combination:

- Global Positioning System (GPS);
- Signpost and Odometer interpolation, both active and passive;
- Ground-Based Radio, such as Loran C; and
- Dead Reckoning

The benefits of AVL include:

- Improved dispatch and operational efficiency;
- Improved overall reliability of service;
- Quicker responses to disruptions in service, such as vehicle failure or unexpected congestion;
- Quicker response to threats of criminal activity (via silent alarm activation by the driver); and
- Extensive information provided at a lower cost for future planning purposes.
3.3 TRANSIT OPERATIONS SOFTWARE

Data collected from vehicle-based fleet management systems is relayed to centralized computer systems and is made useful by transit operations software. This software helps the operator monitor the fleet’s performance in meeting demand, identify incidents, manage response, and restore service more effectively. Paratransit operations software and reporting systems integrate applications such as passenger registration, automatic geocoding, mapping, real-time and batch trip scheduling, dispatching and brokering for multiple carriers. These systems often use a GIS platform that assists in optimizing route planning, and can be combined with an AVL system. Mobile data terminals (MDTs) can be installed in vehicles to display dispatch messages (e.g., passenger pickup and drop-off addresses and instructions), record and temporarily store certain types of information about each passenger pickup and drop-off, and collect statistical and performance data on services provided. Software programs can include billing, and accounting and reporting.

Computer-Aided Dispatch (CAD) systems are currently the most visible software application in fixed-route bus operations. Transit agencies use this software for bus service and operations planning. CAD fixed route software falls into four primary categories:

- Transfer connection protection software
- Expert systems for service restoration
- Itinerary planning systems; and
- Service planning applications

The benefits of transit operations software are:

- Permits optimum use of existing resources
- Assists in evaluation of operational efficiency
- Speeds response to emergency situations
- Improves schedule reliability and operating efficiency
- Reduces per trip cost
- Increases customer service to disabled, elderly, and aids ADA compliance
- Ability to reschedule and re-route transit vehicles

3.4 GEOGRAPHIC INFORMATION SYSTEMS

Geographic Information Systems (GIS) provides a current, spatial, visual representation of transit operations. It is a special type of computerized database management system in which geographic databases are related to one via a common set of location coordinates. This allows information to be developed and displayed to assist operators, dispatchers, and street supervisors to make on-the-spot decisions, and to assist planners in service assessment, restructuring and development. GIS is most often used for:

- Transportation planning and modeling;
- Demographic analysis;
- Route planning, analysis and restructuring;
• Bus dispatch and scheduling;
• Bus stop and facility inventory;
• Ridership analysis;
• AVL and monitoring;
• Paratransit scheduling and routing; and
• Accident reporting and analysis.

4. Automatic Fleet Management System (AFMS) – Case Study

Present case obtained from one of our recent consulting assignments in India. Our client is operating one of the largest Road Transport Undertakings in the country. It has a fleet of around 5,000 vehicles carrying on the business of passenger transport on 800 routes from 33 depots all over the state with a product mix comprising of City and Inter-city services.

The primary purpose is to maintain and monitor information thereby enhancing the performance of RTC services and commuter satisfaction. The focus of AFMS is to automate the RTC's operations utilizing a GPS based vehicle Tracking & GIS based monitoring System and thereby improve the mass transport services. This will provide efficient utilisation of fleet and hence, reduce the cost of operations. This will also help corporate management in introducing new routes and planning. In this process the State government is able to provide better transport services to the commuters and is reducing the cost of operation directly & indirectly and therefore contributing in the improvement of the national economy.

4.1 Objectives

The prime functions of AFMS is to assist in monitoring, control and management of RTC operations as listed below:

• To monitor whether the buses are adhering to its scheduled route and timetable through out the route and identify if there are any deviations.
• To monitor whether the buses are halting at all the scheduled bus stops especially for KM- Scheme Operators, which is resulting in loss of revenue.
• Automatic generation, collection, storage and retrieval and analysis of information related to fleet and thus eliminating human errors.
• Generation of exception reports like deviation from schedule route, timing, Missing Bus stops, Punctuality factor etc. based on captured vehicle data.
• Provide billing software to generate automatically billing details for the buses.
• Dispatching of emergency vehicles to Breakdown vehicles or vehicles in distress, whenever it is sought.
• Provision for integrating Smart Card Readers being supplied by Delhi Metro Rail Corporation.
• Help in working out realistic schedules according to traffic conditions based on speed of bus during different hours of the day and at different segments.
• Provision for Real Time Passenger Information System – both within the bus as well at major Terminuses.

In addition to the above primary functions, AFMS also provides following Secondary functions:
• Vehicles management
• Monitoring drivers & conductors performance evaluation
• Monitoring traffic potential
• Conducting traffic analysis
• Financial accounting
• Personnel information maintenance
• Stores management
• Budget management
• Audit

4.2 Architecture

Designed, developed and implemented the Automatic Fleet Management System that includes Vehicle Tracking System, Application software for billing, Operational Transportation Model for scheduling of buses and integration of Smart Card Reader with the Vehicle Tracking System. It is based on centralized client-server architecture. Further there is a provision for issuing commands to the buses on the roads from either the Central Control Station or from the Depot Control Rooms with proper checks in emergency situations. Information will flow from lower levels to higher levels and vice-versa. Senior officers as well as the Traffic Planning & Analysis department of RTC consolidate information at higher levels on a periodic basis for analysis and decision-making. Figure 3 shows the AFMS system configuration.

4.3 Salient System Features

• GPS based Unit mounted on buses belonging to 2 depots
• Monitoring from a Central Control Station, 2 depots simultaneously. GIS based map display clients along with Application Clients for scheduling of operations and generation of reports using Seagate Crystal Reports. The Clients connect to the Central Control Station that houses the Sun Servers.
• Two Sun Enterprise 250 Servers in a cluster configuration. Application Server is hosted on one of the machines with Oracle 8i database, the Communication Server is hosted on the other machine. The Differential GPS (DGPS) receiver is connected to the Communication Server. User interface for current status information of all connected sub-systems is provided using X/Motif 4.0.
• Display of vehicles at Workstation using ARC Info suite and VC++ based application software
• Real Time two way messaging between Buses & CCS
• Public Mobile Radio Trunking System (Wireless Communication network) for collecting data from buses.

4.3 Benefits to Commuter

AFMS system would be generating exception reports for any bus skipping any bus stop, improper stopping at bus stops, over speeding, deviations from schedules etc. All this would translate into very efficient and effective service and the commuter would now be able to avail trouble free, hassle free transportation. Finally but not the least, there is customized messaging facility available with the driver to alert the Central Control Station with the help of one touch “hot keys”. The two ways
messaging facility can be utilized for emergency conditions like robbery, accidents, breakdown, tyre puncture, riots, traffic jams. In case of traffic jams, RTC can divert other buses on alternate routes and citizens will benefit from reduced disruption in commuting on account of the dynamic routing facility of the AFMS software.

4.4 Benefits to RTC

- Complete Control over the fleet on the road anywhere and every where all the time.
- Facilitate faster exchange of critical information between various departments
- Substantial reduction of paperwork
- Better use of human resources
- Ability to access valid information in minimal time
- Streamlines the related workflow in government machinery
- Centralized database
- Higher efficiency and effectiveness
- Greater coordination
- Instant system-wide alerts
- Messaging feature in case of breakdown/medical emergency provides the driver facility to alert the fleet controllers to provide instant help by mobilizing appropriate resources

5. Conclusion

In India 70 State Transport Undertakings which together own and operate 1,13,000 buses and, provide mobility to 65 million passengers a day, across the length and breadth of the country. APTS technologies along with Fleet Management Systems can make use, to achieve sustainable and environmental friendly transportation for the 21st Century. In addition to the above technologies, institutional and market factors also play an important role in successful ITS deployment for Enhanced safety, Mitigation of environmental impacts of transportation systems, enhanced energy performance, and improved productivity.

ITS has been proved to be the optimal solution to the enigma of building and operating transportation systems to meet expeditiously growing urban travel demand in developed countries. As seen from the preceding sections, technological innovation whether in the domain of data collection, processing or information utilization has been providing the impetus for ITS development. Accompanying the benefits of better performance and cost effectiveness, these technological innovations give rise to the challenges of implementation (integration), support and funding. Scalability and adaptability to current and future local user needs are seen as the key factors influencing selection of the appropriate technology.

6. Acknowledgements

Authors would like to express their gratitude to TCS-CMC the largest Indian Software and Management Consultancy firm, facilitating to explore innovative methods in Transportation Industry Practice. Thanks to its Technology Focus, Worldwide presence and adherence to the highest quality standards (ISO 9001 and SEI CMM level 5).
Figure 3: The overview of the system configuration

7. References

This study has benefited from the collective wisdom of the members of the Transportation Industry Practice–ITS group at TCS-Mumbai. The Group’s brainstorming sessions and discussions helped in bringing together a coherent thought process while implementing the ITS sector development initiatives.

www.itsa.org
www.iteris.com
www.its.dot.gov
www.veritis.com
www.tc.gc.ca
www.ertico.com
www.ewh.ieee.org/tc/its
www.nawgits.com
www.path.berkely.edu
www.itsindex.com
www.its-network.com
www.standards.ieee.org
www.ntcip.com
www.itsworld.com
www.ieeexplore.ieee.org