Development of Toolkit for implementing ITS – Public Transport & BRT Services

MINISTRY OF URBAN DEVELOPMENT
GOVERNMENT OF INDIA

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Toolkit on Intelligent Transport System for Public Transport & BRTS

MINISTRY OF URBAN DEVELOPMENT

The Institute of Urban Transport (India) is a premier professional non-profit making organization under the purview of the Ministry of Urban Development, Government of India (MoUD). The National Urban Transport Policy (NUTP), 2006 has empowered IUT to serve as a National Level Facility for continuous advice and guidance on the principles of sustainable urban transport. The objective of the Institute is to promote, encourage and coordinate the state of the art of urban transport including planning, development, operation, education, research and management at the national level.

The Institute has been nominated as the project monitoring unit for Component 1A of the SUTP. IUT is responsible for overseeing the preparation of the training modules, subject toolkits and conduct of training of 1000 city officials in urban transport.

The Ministry of Urban Development (MoUD), Government of India (GoI) has initiated the Sustainable Urban Transport Project (SUTP) with support of Global Environment Facility (GEF) and the World Bank to foster a long-term partnership between GoI and state/local governments in the implementation of a greener environment under the ambit of the NUTP. The aim of the project is to achieve a paradigm shift in India's urban transport systems in favor of sustainable development. The project's development objective (PDO) is to promote environmentally sustainable urban transport in India and to improve the usage of environment-friendly transport modes through demonstration projects in selected cities.

The Centre of Excellence in Urban Transport, CEPT University (CEPT-CoE), established in 2009 is an initiative of the Ministry of Urban Development (MoUD), Government of India and is supported by the Ahmedabad Municipal Corporation. CEPT-CoE has been envisaged as a resource centre for dealing with issues in urban transport planning and management. It has a mandate to cover three aspects of capacity building in urban transport - human resource development, knowledge management and technical assistance & advisory.

The Centre has been providing technical assistance to the MoUD on urban bus specifications and has been contributing to numerous national committees, working groups and government led missions / projects related to urban development and urban transport in varying capacities.

Acknowledgement

The Centre of Excellence Urban Transport CEPT University expresses its sincere thanks to the Ministry of Urban Development (MoUD), Government of India, for awarding the work of preparation of toolkit on "Intelligent Transport System for Public Transportation and Bus Rapid Transit System"being prepared under Sustainable Urban Transport Project (SUTP) jointly initiated with the support of Global Environment Facility (GEF), United Nations Development Programme (UNDP) and World Bank.

Finally, we would like to thank the following individuals for their contributions and making this document a valuable resource:

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Contents

Abbreviations

AFC	Automatic Fare Collection
AJL	Ahmedabad Janmarg Limited
AMC	Ahmedabad Municipal Corporation
AMTS	Ahmedabad Municipal Transport Services
AVM	Automatic Vehicle Monitoring
AVLS	Automatic Vehicle Location System
BI	Business Intelligence
BRT	Bus Rapid Transit
CCC	Central Control Centre
CCTV	Closed Circuit Television
CIE	Coras Iompair Eireann
DOT	Department of Transportation
DVR	Digital Video Recorder
EMS	Enterprise Management System
FMS	Fleet Management System
GIS	Geographic Information System
GPS	Global Positioning System
GPRS	General Packet Radio Service
GSM	Global System for Mobile communications
GSRTC	Gujarat State Road Transport Corporation
ICT	Information and Communication Technology
IP	Internet Protocol
ISD	Information Services Department
ITS	Intelligent Transport System
JnNurm	Jawaharlal Nehru National Urban Renewal Mission

LAN	Local Area Network
LCD	Liquid Crystal Display
LED	Light Emitting Diode
MIS	Management Information System
NMT	Non-Motorized Transport
NTA	National Transport Authority
PA	Passenger Announcement
PC	Personal Computers
PCU	Passenger Car Unit
PIS	Passenger Information System
PSO	Public Service Obligation
PTZ	Pan Tilt Zoom
RFID	Radio Frequency Identification
RTPI	Real time passenger information
SAM	Secure Asset Management
SLA	Service Level Agreement
SME	Subject Matter Expert
WAN	Wide Area Network
VCR	Virtual Cassette Recorder
VPN	Virtual Private Network
VSD	Vehicle Scheduling and Dispatching

QUICK REFERENCE:

ITS background information and purpose of toolkit

This section provides insight into the fundamental behind the ITS implementation, need and handholding process to familiarize different stakeholder with the process adoption.

Key considerations and elements to consider for ITS implementation

This section provides information about the how expectations from ITS system should be baselines and what are the critical elements, which should be provisioned to deliver intended results out of ITS implementation.

Step-by-step process flow and ITS implementation phases

This section provides step wise approach to implementation and selection of ITS elements and outlines approach to institute a process to implement the project in a defined and informed manner.

Functional requirements and Applications to use for ITS

This section provides deep insight into functional requirements while implementing ITS in-order for organizations to rightly map their specific requirement with reference to organization specific need and approach.

ITS Technology considerations

This section provides deep insight into tools and technologies available in market place and services provider ecosystem. This section would enable organizations to handpick technology and tool to specifically meet the requirements as articulated after clearly defining functional and delivery requirements.

Reference case studies of developed and developing countries

This section provides detailed case studies related to ITS implementation across several regions in the world. This section should be able to offer insight into city specific implementation and also offer some base lining data to compare with the organizations wanting to implement ITS.

Note:

The P2I process described in section 4 of this document should be applied to all the other sections to derive processes that may be needed to be re-oriented with individual functions to rightly deliver ITS supported organization. This would help to realize early benefits through implementation of ITS.

Chapter 1

1 INTRODUCTION

The ITS Toolkit for Public transport and BRT services is a reference guide that can provide basic understanding of all aspects of ITS to improve efficiency of transportation services leading to higher service usage. The toolkit is prepared based on the implementation experience by different stakeholders including the urban transport managers and it provides insight into the planning perspectives, which would support step-by-step implementation of ITS for Public transport and BRT while keeping in mind the demographics of the implementation city.

1.1 Objectives of this toolkit

The objective of the ITS toolkit is to aid stakeholders with understanding all aspects of ITS, offer guidance to transport managers with necessary information to plan technical specifications along with evaluation criteria for critical factors while implementing ITS, offer guidance related to ITS deployment technologies, procedures and applications required to support implementation initiative considering the existing Indian transportation services scenarios and the resource and skill sets required based on the respective work culture/policies followed by the cities. The toolkit delivers a step by step guide that helps urban transport leaders, and the organizations they lead, to plan, design and implement ITS to improve the efficiency and attractiveness of the passenger transport system in their cities.

The toolkit provides useful information to key stakeholders with urban transport system to clearly surface:

- Planning Objectives
- Design Considerations
- Implementation needs
- Evaluation Criteria's
- Investment decisions
- Benefits and Improvement Opportunities

The applications covered in the toolkit are based on implementation experiences and initial needs assessment of the function that is applicable to planning, delivery and use of public transport system. However, public transport ITS is undergoing a change at phenomenal rate, simply because of the global focus on green initiatives and PT centric urban planning initiatives, the advancements in its applications and technology is also changing at a faster pace.

The toolkit highlights the role of technology perspective to manage the public transport activities in a highly coordinated manner leading to a high productivity environment, efficiency and reliable services to the users, apart from the highly tangible benefit of service sustenance and continual improvement based system. It focuses on only public transport and BRT services and does not address ITS applications for other transport modes such as private cars, ferries, peddle cycles, auto rickshaws etc.

1.2 Target groups for the toolkit

The target users for toolkit are key stakeholders like Governments/Public administrations, Transport authorities & operators, ITS consultants and Authorities of public transportation services with interest to offer ITS etc. including investment and funding agencies which would be considering implementing or upgrading ITS application for urban passenger transport.

1.3 ITS definition and characteristics

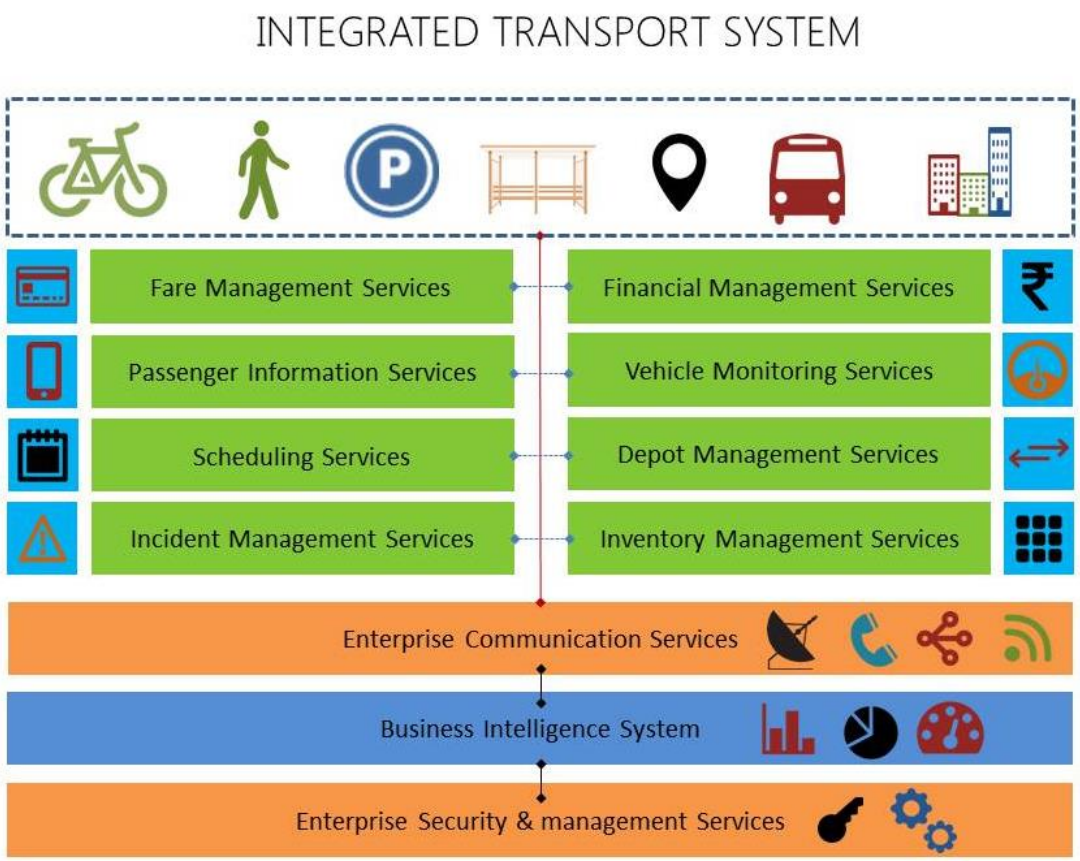
Intelligent Transit System (ITS) is an integrated technology approach to enhance the efficiency and offer coordinated operations management support to public transit operators, which is a continual challenge for public transport authorities and operators alike. With the expansion and development of ITS, there has been an increasingly wide variety of emerging ITS concepts along with applications and technologies which would benefit commuters, transit operators, public transport authorities and various other stakeholders.

Given the fact that most of the Indian cities are densely populated, increased use of public transport system would reduce requirement of building more roads and the current capacities can be utilized to move more people. However, in most of the Indian cities, public bus transit service are characterized by inadequate investment in services, constrained by operational issues, declining ridership, declining productivity, and persistent losses despite changes in the infrastructural environment. The ability of transit managers to rightly investigate and have access to operational parameters is hampered by the absence of integrated and intelligent operations environment, which could be made available to them by rightly selecting and operating adequate ITS intervention.

Intelligent Transport Systems, in Indian cities context, involves customized, situation-specific applications to address specific requirements. ITS comprises of functional applications delivered using state-of-art computing, network and communication infrastructure with a clearly defined aim to improve the efficiency and effectiveness of public transport & BRT services, which would benefit commuters, transit operators and public transport authorities alike.

The main ITS areas/applications identified, which perform real-time integrated functions are:

1. Revenue Management
2. Operations Management
3. Infrastructure Security Management
4. Business Intelligence Management
5. Management Information System
6. Traffic Management
7. Financial Management
8. Enterprise Management System



1.4 Toolkit Structure and components

The toolkit comprises of five parts:

- **Key considerations** - the key consideration points to be analyzed before concluding on the ITS applications & technologies to be utilized in the respective cities.
- **ITS Program Guidance** - the step-wise processes & procedures that should be followed for planning, design, implementation and evaluation of proposed ITS system.
- **ITS Applications** - the use of ITS for public transport functions. These functions/applications are grouped into the following categories: Revenue management, Operations Management, Infrastructure Security Management, Business Intelligence system, Management Information System, Financial, Traffic and Enterprise Management Systems.
- **ITS Technologies** - The technical systems and hardware required by the ITS applications. These applications are grouped into the categories: Automated Vehicle Location System, Automated Fare Collection System, Passenger Information System, Automated Scheduling and Dispatch System, Incident Management System, Traveler & Asset Security System, Communication Systems, IT security and Depot Management Systems.
- **Case Studies** - covering the 5 countries/cities that followed ITS and the challenges/benefits accrued by them. The case studies narrated are for: Dublin, Ireland, Zurich, Switzerland, Izmir, Turkey, Ahmedabad, India & Curitiba, Brazil.

Chapter 2

2 KEY CONSIDERATIONS OF ITS IMPLEMENTATION

There are a few key points that need to be kept in mind before proceeding with the implementation plan of Intelligent Transport Systems in the cities:

i. Intelligent Transport Systems uses advanced technologies but they are still dependent on the Socio-economic, Geographic and Organizational & Cultural environment existing in the implementing cities. It is important to identify the goal(s) for the transport improvement program before examining the appropriateness of an ITS-led approach in the Indian context.

ii. It is prerequisite to have co-operation and willingness of all the stakeholders to change organizational and operational processes (wherever necessary) followed by the existing transportation services in order to bring in innovation and increased opportunities created by Intelligent Transport Systems.

iii. ITS not only brings in investment cost associated with it but it also carries ongoing management and maintenance cost, which may be quite significant. The investing stakeholders needs to have the capacity to manage these implementation and ongoing cost before deciding on the ITS program.

iv. Intelligent Transport Systems implementation is a program to enhance the existing transportation services of the cities to a reasonable extent. It is not a means to make up for the poorly managed and organized public transport systems.

v. The implementing cities might not have direct and immediate financial return from the Intelligent Transport Systems and they are not cheap to implement either. They are the means to enhance the usability of the transportation services and thereby increase the commuters travel delight and ridership.

vi. ITS is often easier to fund in the public sector, where returns may be evaluated against economic as well as financial criteria. However their opportunity cost should be assessed against other local expenditure priorities, especially where resources are constrained.

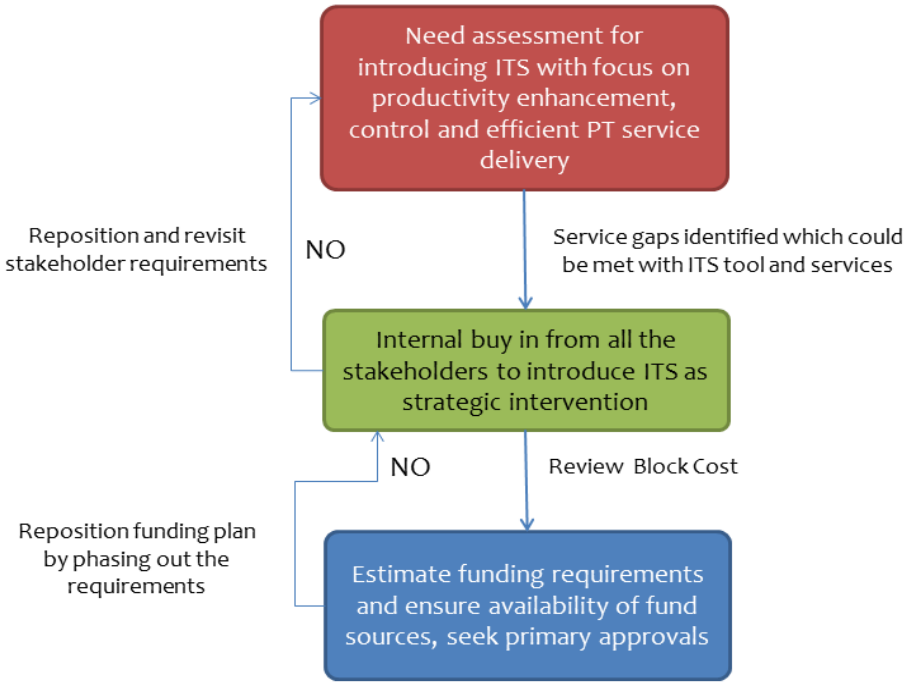
vii. Electronic fares collection may prove to be the Intelligent Transport System with the highest financial return. Any success in this domain could act as a technical platform and also provide funding support for future enhancement programs.

viii. It is important to consider that a connected transport service is safer, more economical, more ecological and opens up a whole new array of services with the development of ITS and encourages multimodal transportation.

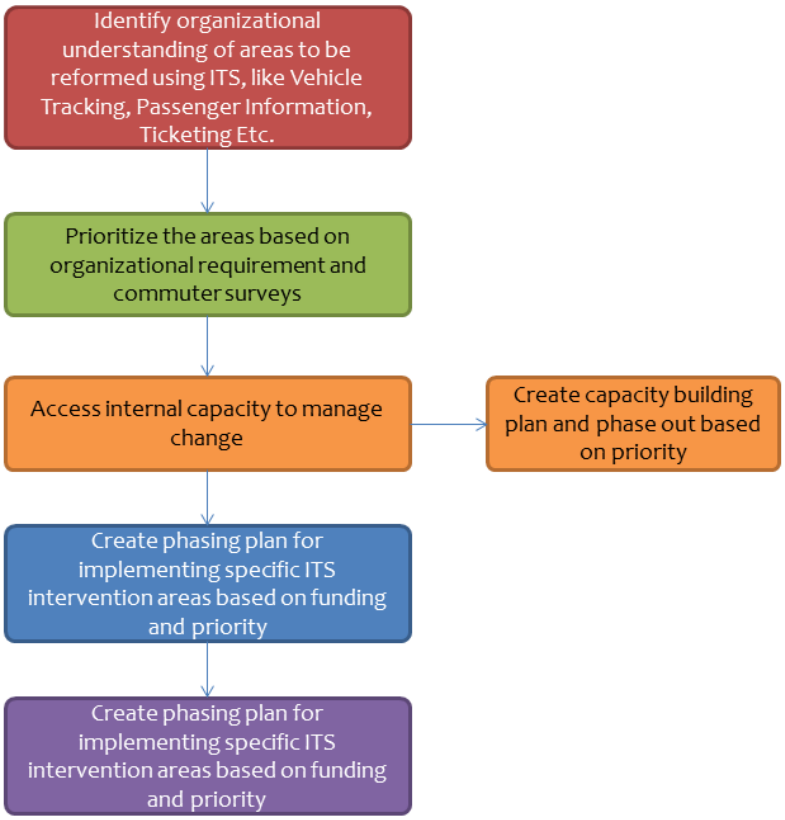
ix. ITS is one of the levers that makes it possible to limit traffic congestion and reduce environmental pollution thereby encouraging democratization of transport and mobility for all.

Below are the decision areas that need to be considered that shall aid decision makers in ITS implementation assessment:

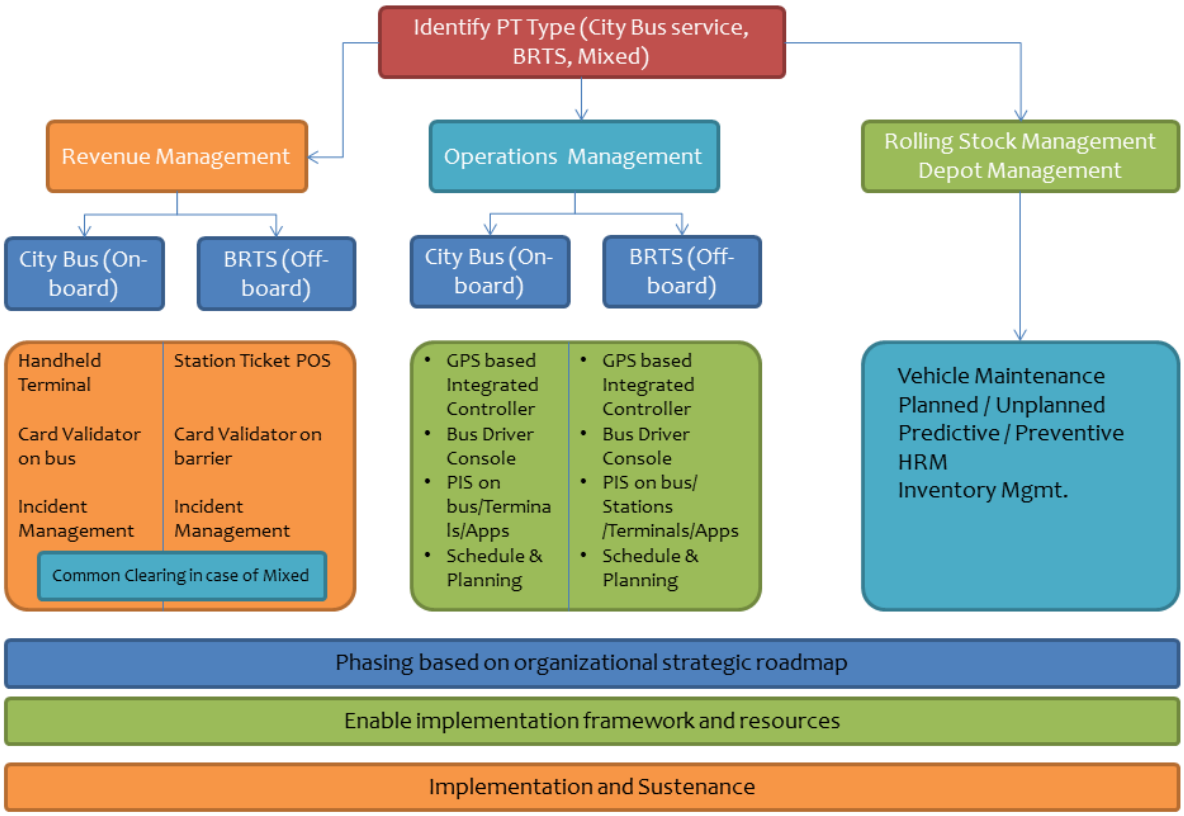
Assessment and Organizational Readiness for ITS Implementation



Strategic Thrust area Identification



Identify Relevant ITS Tools and Technologies

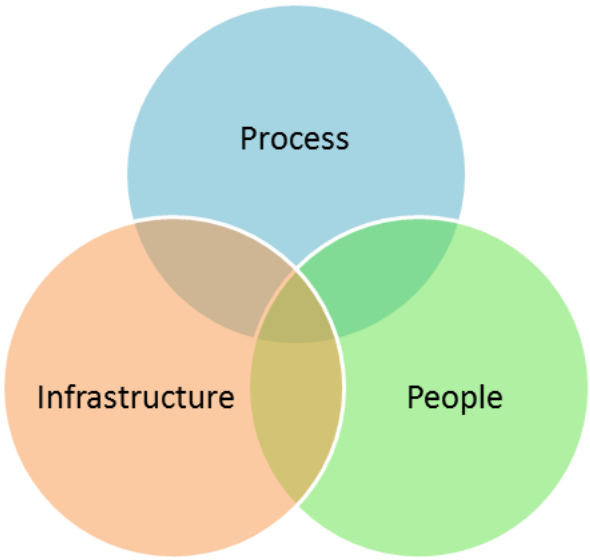


Chapter 3

3 P2I CONNECT PROCESS

Transformation through ITS intervention requires three important elements within organization to collaborate at desired levels for the purpose of achieving objective from the intended implementation. ITS in isolation can never deliver intended results unless and until all the above stated elements work in unison to deliver results. Hence, the toolkit shall focus on all the aspects stated above to identify change requirement to successfully implement and sustain ITS initiative.

The three important elements as stated above are (**P2I Connect**):



1. Process
2. People
3. Infrastructure

Process:

The process generally relates to capability of an organization to respond to situations in a similar manner as and when they occur irrespective of the people involved in managing such events. Hence, requirement of development of standard operating procedures mapped to the delivery requirements is absolutely essential to derive efficiency benefits and consistent service delivery based on the ITS platform. ITS upgrade should be backed up by appropriate process change management and bound by standard procedures to institutionalize the change and thereby accrue intended benefits from the intervention. The standard operating procedures are subject to continual change depending on the situation and organizational learning processes and hence it is a pertinent requirement to employ

matured change management processes and designate change agents to percolate such changes across the organization and relevant stakeholders as and when they are validated to be deployed within the organization.

People:

The resource skill set and subject matter expertise is one of the very important factors which contributes to the successful implementation and sustenance of ITS implementation. Institutions need to carry out assessment of skill required to operate and sustain ITS and if found deficient, the organization should focus on on-boarding required competences in order to successfully implement, monitor and sustain the ITS implementation. Most of the organizations in Indian context would on-board an implementation agency through relevant procurement processes , but in-order to effectively manage the agency deliverables and business continuity planning, minimum skill types that would be required would be as follows:

a. Transport Planner

b. IT expert

c. Intelligent Transit Systems Expert

The above mentioned skill sets would bring in required knowledge base to rightly assist selection, implementation, management and sustenance of the envisaged ITS modernization initiative.

ITS infrastructure:

The right set of ITS infrastructure in terms of hardware, software and communication systems would be needed to be deployed to achieve intended results via ITS implementation. The initiative is required to focus on set of capabilities which would enable organization to deliver commuter oriented services, which would instill confidence, reliability and safety in the minds of people using public transportation services. It is imperative that organization harnesses capabilities to deliver services in a highly controlled manner using latest ITS technologies. The basic areas of intervention should be focused around ability to manage bus operations in real-time to deliver services at intended levels which would contribute to commuters increasingly making public transport as choice of travel. A Central Control Centre is also required to be in place which should be fully operational during the operating hours of operations. The control center should be staffed with people who can act as an interface between the deployed system and its planned outcomes. Guided by defined set of protocols and standard operating procedures, the control center also acts as the process owner of Incident management system, emergency response system, scheduling compliance and the communication hub of all information within the system.

Chapter 4

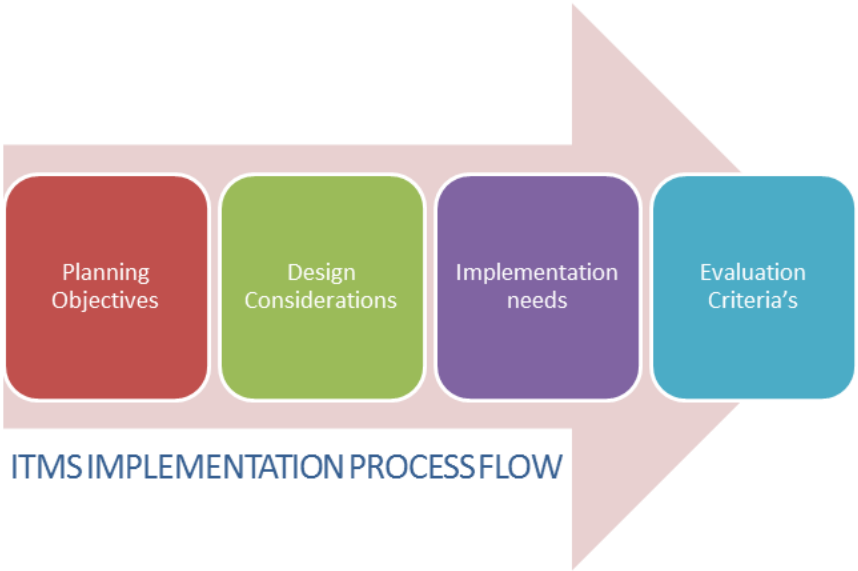
4 PROGRAM GUIDANCE - PROCESS FLOW

The Toolkit provides guidance on the desirable activities that should be undertaken by the policy and decision group, transport managers and implementation line managers depending on the level of intervention and impact thereby on the system and outcome.

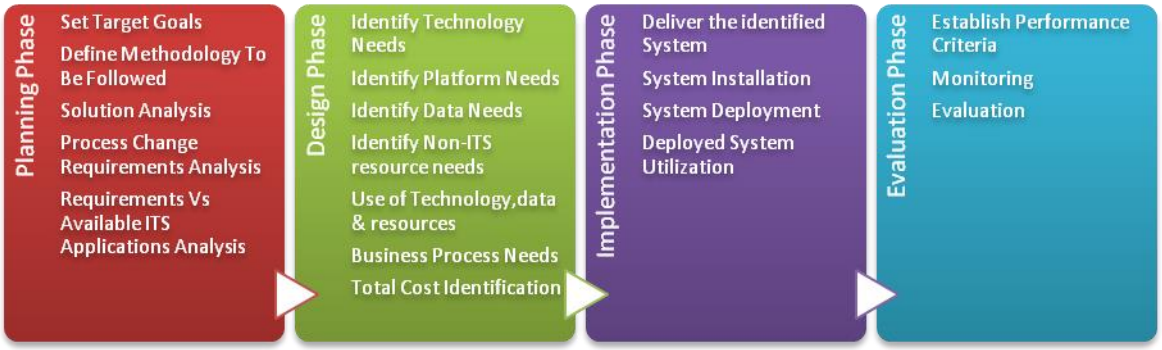
The toolkit provides guidance in a methodical manner from goal setting and planning, through detail design and procurement, to implement and getting best use from the investment made into ITS. The toolkit provide actions to be taken at each phase of the ITS implementation, including advice and risk identification based on wide range of international experience.

This toolkit is structured into following phases of ITS deployment project, with evaluation phase being perpetual:

- Planning Objectives
- Design Considerations
- Implementation needs
- Evaluation Criteria's



Below shown process flow is the summarized view of the ITS implementation phases and their respective sub-components:



4.1 Planning Phase

The planning phase provides insight into the structured process that needs to be followed by the policy-makers and investment decision makers on what is ITS required to do and how ITS would assist in resolving the existing issues in transportation services within the implementing cities. It covers - objectives & requirements of ITS, methodology to be followed, how the system would perform and the ITS applications to be implemented that are tailored to the implementing cities context.

There are planning areas that need to be considered by the implementing organization:

- Goals to achieve through ITS implementation
- Methodology to be followed to achieve above set goals
- Is ITS the only solution or do we need process improvement as well
- How much would ITS system achieve and how much do we need to change our processes
- Relevant ITS applications to consider viz-a-viz requirements identified

4.1.1Goals to achieve through ITS Implementation

Goal-setting is the first step towards making purchase and deployment decision in any ITS. It is very important to have clarity on the reason for which ITS system is being considered and how it is expected to assist the public transport organizations, commuters and other stakeholders. Goal-setting is a strategic task that is envisaged by the decision makers and policy makers along with relevant management layers of the stakeholders.

As per the studied international case studies, most of the times the ITS systems are implemented with the pivotal aim of solving existing problems (e.g. Decline in service quality and chaotic traffic congestions), to improve performance (e.g. Dispatch management), and to provide information needed for improved management and productivity (e.g. MIS, scheduling). Cities are also looking to solve transit integration issues by way of implementing appropriate technology to achieve fare and ticket integration. Apart from these core reasons,

ITS is introduced as an upgrade of the existing transportation services through brought-in advanced technology with the help of ITS and offering new services to the commuters (e.g. real-time passenger information) or to avail opportunities (e.g. link to the traffic signal system for priority for buses) etc.

The Goal-setting process ensures that the key stakeholders have a shared understanding, that the ITS is relevant to the public transport business to achieve implementation objective, and that the technology implementing agency is given clear guidance.

4.1.2 Methodology to be followed to achieve above set goals

The goals represent the strategic approach. The next step is to identify a set of needs and solutions from the stakeholder goals.

Based on the goals set by the stakeholders and the perceived needs as high-level requirements of the organizations, ITS systems are designed and deployed to suffice these requirements. Some of the examples of these end-result targets are – achieve automated revenue management systems, achieve higher operating speed, reduce variability of journey times, or minimize accidents or unsafe driving. The relevant needs identification allows stakeholders to not only come up with better solution driven decisions but to mitigate the risk associated with them as well. The output of this activity would be a needs assessment or user requirements document.

Having identified the organizational needs, various solutions are identified and analysed. 'Solutions' are the approaches the organization(s) can take to meet their needs. The solutions are typically at organizational, operational or customer services level. For example, if the Need is to reduce variability of journey times, one Solution could be establishing an effective operations management capability by implementing automated scheduling and dispatching system.

This stage provides a framework for discussion and consensus forming among and within the stakeholders. It also provides a reference point for alignment with other initiatives.

4.1.3 Is ITS the only solution or do we need process improvement as well

In most of the cases, the needs identified and the proposed solutions need not be the goals that could be achieved by ITS itself. ***"It is worth questioning - if ITS was not available to us, how much of our goals could we achieve by improving our organization, our approach, and our operational problems?"***

In few cases, it may indeed be possible to achieve the main goals without deploying ITS. In far more cases, the exercise will reveal improvements that should be made whether or not ITS is implemented. Nonetheless, it is important to seriously reflect on whether deploying ITS is the only best approach to take. For example, the real underlying problem could be human centered problems like poor

timekeeping, careless driving, lack of incentives etc. which could be solved through proper staff selection & training, monitoring and disciplinary action etc. There could also be organization centered problems like lack of ownership and accountability that could be solved by setting clear roles & responsibilities and increasing accountability.

These are management issues, and technology will not solve them. More importantly, if they are not identified and resolved in parallel to the technology deployment, the ITS will not achieve the expected benefits.

4.1.4 How much would ITS system achieve and how much process change needed

Once the strategic requirements are finalized and the responses at tactical level are decided, the next step is to describe in detail how this will be implemented. It must begin with a thorough understanding and review of the organizational structure, its business processes, and the operational processes within which the ITS system will reside.

At this stage, it is very important to refer to the international case studies and avoid repeated failings like implementing ITS by replicating how existing processes are followed or by overlooking organizational structures and process changes. The consequences of these failings would be, not only missing out the expected benefits of ITS deployment but also restricting the future advancements that ITS can bring in.

Good practice is to carry out the following steps:

- Carry out a full process review for all of the functional areas within the scope of the ITS analysis
- Carry out an opportunity analysis to see where and how these processes and their organizational structures could be improved
- Define all new and amended processes
- Develop the functional requirements for the ITS, with clear linkages between the processes and the ITS functions
- Define the new operating procedures

The detailed design will provided deeper understanding of the risk, opportunities, constraints and the costs involved in ITS deployment and support in better functional requirements documentation. These functional requirements not only describes the existing business processes and the need for change in the business processes but also highlights how the system and its components would assist them. They provide the primary reference for the technical design of the ITS.

The best way to quantify the above activity in terms of benefits tangible and non-tangible, is to carry out benchmarking exercise. This activity would enable organization to clearly understand current service levels and also enable them to set achievement standards. ITS should be used as an intervention tool to achieve operational and organizational excellence towards service delivery. This

activity will clearly identify roles and responsibilities and also aid development of realistic change management framework which would deliver the perceived value.

4.1.5 Relevant ITS applications to consider viz-a-viz requirements identified

At this stage, number of possible technical solutions are analyzed and assessed. The technologies are ever changing these days, offering new approaches, products, cost and managerial propositions and so it is very important to keep an open mind at the potential technical solutions that could be considered for implementation.

The inputs from previous steps of need assessment & solutions and Functional Requirements are the major determinants of the technical solutions which are considered. Other influencing factors will be current and emerging practice in the transportation domain, existing ITS systems, operating environment, available means of communication and data transfer, available IT support, costs, development risk and deployment risk associated with the implementing city.

The transportation entities may also have a considerable impact on technology aspects, especially the corporate form, number of operators and number/size of vehicles. It is always advisable to consider the factors like functionality, performance, investment cost, life cycle cost, durability, complexity and the implementation risks associated with the finalized technology options.

Based on these factors, the decision makers come up with the preferred technology that should be considered and the migration path that needs to be followed based on the technical and funding capacity of the implementing city. A preliminary costing should be prepared and presented to the relevant stakeholders to gauge the willingness to finance it, as there is little point in persisting with this approach if the funding will not be available.

4.2 Design Phase

Design phase is the subsequent step after the planning phase and at this stage the transport managers/authorities targets at detailed technical design including the platform strategy that would be followed. This phase also considers the operational and technical resources requirements along with the data requirements and the approximate funding estimates to ensure strategic implementation plan for ITS.

It covers all the aspects of the technical design and at this stage, all the technical issues are identified. A reasonable estimate of implementation and ongoing costs should have been made and approved at this stage and as and when new perspectives are highlighted till this stage, the initial functional requirements are revised accordingly in order to come up with best implementation approach.

There are seven steps in the design phase that needs to be followed:

- Identify Technology needs

- Identify Platform needs
- Identify Data needs
- Identify non-IT resource needs
- Use of technology, data and resources
- Business processes needed to change to take full advantage of ITS
- Total cost Identification

4.2.1Identify technology needs

Once the functional requirements are identified and agreed upon, broader perspective of technology can now be envisaged. The next step is to determine the specific technology solution with the focus on the systems and device types to be used and where they are located, intelligent functions and communication elements of the whole system. This is the phase where detailed analysis and description of the technology architecting is drafted i.e. ITS technologies to be deployed in sync with the described functional requirements of the stakeholders.

For the cities following ITS for the first time, it is always advisable as a reference point, identify what other successful authorities have followed while deploying ITS and not just rely on the practices within in the industry. This is a safe approach if steps 1 to 5 have already been taken and if there are resulting well-developed functional requirements and technology options based on an analysis of goals and needs. The technologies to be used need to be considered from four perspectives:

- **System/sub-system:** The functions performed by the ITS system, e.g. Operations Management, Fare Collection, Surveillance, Precision Docking etc.
- **Location:** Where the technology is located, e.g. on vehicles, at the control centre, at bus-stops
- **Technology type:** The nature of the device, e.g. customer-facing equipment, sensors, data processor, communications device, data storage units
- **Role:** Generate data (e.g. sensor), process data (e. g. card reader), display (e.g. at-stop information display), analyse data (e.g. dispatch support), optimize resources (e.g. scheduling)

Many devices have multiple embedded components and they may perform multiple functions. For example, a suitable GPS-enabled mobile phone may now be sufficient to support AVM functions, where previously it would have required a radio, a GPS unit, a driver interface/console and an integrating processor. Similarly, individual devices may now perform multiple functions, or a suitable combination of two devices and shared processing may eliminate the need for a third device.

4.2.2 Identify Platform needs

The next step here is to conclude on the system architecture and their communication with integrated systems. An ITS System consists of many interconnected devices, software and information. At a minimum, they need to be able to connect to each other and exchange information. The ITS systems and sub-systems may need to be able to perform tasks together. In many cases, the

new ITS systems will need to interface with the existing or legacy systems of the transport entities, or interface with external systems such as the traffic control centre.

Correct interfacing of systems can only occur if it has been properly planned for. This is one of the most underestimated aspects of ITS systems. It is all-too-often ignored or given minimal attention until procurement or even operation is well advanced, and then problems start to emerge (e.g. during installation). By this stage, it can be very costly and/or time-consuming to resolve. Sometimes, fixing the problems (or even admitting to them) is considered so much trouble that the consequences are left to someone else to solve later and the problems are lived with until they can no longer be ignored.

Examples of avoidable problems (which are often encountered in ITS deployments) are:

- Problems with wiring and installation of different ITS equipment on buses, due to a lack of a comprehensive wiring and communication diagram.
- Improper integration of new devices with the existing ones due to lack of existing infrastructure devices that could recognize the new ones.
- Inability to interface different ITS systems and the missing comprehensive data model.

The core ITS "platform" elements are:

- **The System Architecture,** which provides a 'blueprint' of all the ITS systems and how they relate to each other
- **The Communications Architecture,** which defines both how the systems and devices talk to each other, and the content of the information to be exchanged
- **The Data Model,** which provides a consistent definition of all data to be used in the transport entity, so that each (sub-)system describes the same things in the same way
- **Interfaces,** which define the physical connectivity between devices and the protocols used for information exchange
- **Standards,** which ensure that both Vendors and Clients develop hardware and software in a common way, usually based on international industry consensus

The appropriate ITS platform elements are determined by the deployment teams based on the international best practices and standards. This leads to significant benefits in terms of dynamic and robustness of design, and ability to source different vendors for different ITS systems. Now a days, most of the valued suppliers of ITS systems perform based on the international good practices and standards and this becomes a problem for the suppliers only when the client fails to provide defined framework within which they are expected to perform or when it favors one supplier over the others.

4.2.3 Identify data needs

The next step is to define on the data requirement from the described ITS technology. The application software of ITS systems is highly dependent on data. It is also the task of many ITS applications to generate, collect, store or transfer data. The data requirements will come into a number of broad categories:

- Support data which the ITS system needs to carry out its functions (background data, configuration data, daily assignment data)
- Real-time or event/transaction-specific data which the ITS requires when it is performing a specific function. It may generate this data itself, or receive it from another device or system
- Data which the ITS system should pass to devices, both for immediate and downstream use

There are various categories of data that are utilized by the ITS systems i.e. Background data, configuration data, operational data, sensor data, real-time transfers into and out of ITS devices and applications and data for analysis and reporting etc. This is a technical activity that requires expertise and experience. There is considerable scope for transferring and re-using materials from industry good practice and from other successful ITS systems. Nonetheless, it is very important that any such replication is carefully adapted to the needs of the deployment location, and is fully in sync with the functional requirements and technology/platform requirements.

4.2.4 Identify non-ITS resource needs

Occasionally, a ITS system may be free-standing or can be plugged into existing ITS systems without any other requirements. However, most ITS systems are not independent and they require supporting infrastructure and back-office support. Three particular aspects need to be considered:

- The ITS system may need to share some of the IT platform of the host organization (e.g. servers, communications, operating systems). Platform capacity may need to be increased and additional user licenses purchased.
- The ITS system may need to interface with the existing administrative and/or management IT systems. System software amendments may be needed.
- The ITS systems may also need non-ITS supporting technology including communications, servers, back-office PCs, printers, office software and security software.

There are additional technology resources like communications, servers, peripheral devices and office & security software that are required by the deploying site apart from the ITS related resources. Human capacity requirements are also to be considered, not necessarily adding more number of resources, at end-user, trainers, software management and maintenance & problem-solving levels as well. These requirements need to be identified, specified and budgeted for as part of the ITS system design and planning.

4.2.5 Use of technology, data & resources

ITS systems and the information they generate may suffice the functional requirements of the stakeholders, but it always provides additional potential to deliver more than what they are designed to do and exploiting this additional opportunities that arise from these ITS systems would not only share the cost structure of the ITS systems but also generate additional revenues to them.

Opportunities tend to arise at specific phases - during the design, after implementation, and when new devices or more advanced technologies (e.g., distributed processing) are added. Quite often, the greatest benefit can be gained by other departments of the transport operator, which perhaps did

not really understand the ITS at the beginning or whose needs were not included in the analysis. This is why it is essential to include representatives from all parts of the organization in the design phase.

It is advisable to establish a culture of continuous development, which seeks to advance the usefulness, efficiency and productivity of the ITS investments. Many enhancements require only modest investment, and others can actually make cost savings within the organizations. In cases where an enhancement would be expensive or difficult to implement as a stand-alone action, it could be included in a later general upgrade or renewal of the ITS.

4.2.6 Business processes needed to change to take full advantage of ITS

There is always a possibility that the existing processes and procedures followed by the organization may not be effective and need improvement/change in order to get in sync with the ITS systems. The ITS deployment requires some of the organization change or business process changes as a core enabler of the new processes. These changes could be effected before or after the ITS deployment as the possibilities are analysed.

At the time of the first ITS implementation, many transport entities are not able to fully envision or appreciate the potential of the ITS or they do not know how to harness it. Following a learning period, the potential can be exploited in subsequent deployments or when they are renewing older systems.

Change to organizations inevitably occurs when ITS systems are implemented. The greatest advantage is achieved when ITS is implemented because the organization seeks to change – and hence the organizational change actually drives the process – compared to some organizations where change is a reaction to a new technology.

The changes could be related to organizational structure, business processes, operating procedures, human resources and skill sets, management and performance assessment etc. The amount of change and the impact of changes to these areas depends on the level & scope of ITS implementation in the city and the enabling factors governing that city.

4.2.7 Total cost identification

The cost of the ITS system needs to be estimated at various stages in the specification and design process. The initial estimate is usually an order of magnitude costing, based on typical costs in the industry. As the design becomes more specific to the host environment, a more accurate estimate of costs can be made. The costs should be considered from three perspectives:

- Initial investment, including both equipment costs and the cost of installation/deployment
- Ongoing operating costs
- Life cycle costs, including upgrades and added functionality.

Failure to do so could lead to problems at the procurement stage if the price of the most suitable bids turn out to be well in excess of the available budget. This could lead to project failure, or major downgrading of the functionality, or a reduced number of locations where ITS devices are deployed.

The three most common causes of cost escalation are:

- Software development turns out to be far more complex (and hence more costly) than originally expected
- "Mission Euphoria" as more and more functions and devices get added to the ITS project
- technology Bias (on the part of the leaders or of the technologists), so that more advanced and costly equipment is specified than was really needed to do the job

It is not necessarily a problem if the actual project becomes more expensive than the original estimate, especially as the added-value may also increase. The important point is that any cost escalation is known to the decision-makers, can be justified, and the extra cost is provided for.

For the purpose of understanding costs associated with different components within ITS spectrum following information can be used to approximate fund requirements with respect to size of operations.

Hardware

Sr. No	Item	Approximate Cost Range (Rs)
1	Smart Cards (includes printing on both sides)	30 - 75
2	Bus Driver Console – GPS (as per Technical Specifications of RFP document - Bus electronics Data System for CNG/Diesel Buses is part of Bus Driver Console)	225000 - 275000
3	Single Journey RFID Token	20-35
4	PIS Display – Bus (unit of 3 Displays per bus)	200000-275000
5	Station card validator for access barriers to be installed on flap barrier/ turnstiles.	75000-90000
6	Station Ticket Terminal (POS) with Cash Till (STT)	75000 - 95000
7	Bulk Initialization Machine	750000-1200000
8	Card Personalization Device	125000-175000
9	Station Server	45000-75000
10	Station PIS Display Unit (as per technical specifications of RFP document)	90000-150000
11	Communication Unit for Bus Stations for AFCS and PIS etc. (in case of BRT)	200000-300000
12	Control Centre Hardware including video wall, servers, LAN/WAN equipment's etc.	25000000 - 35000000
13	Handheld terminals for Ticket Inspection	30000-75000
14	Printer at station	12000-15000
15	Flap Gates	250000-350000
16	Depot Hardware	1200000-1500000

Sr. No	Item	Approximate Cost Range (Rs)
17	Call Centre Hardware includes, Desktop PC with call handling equipment	45000-65000
18	EPABX for Call centre with at-least capacity of 50 Lines scalable to 300	150000-250000
19	55" LCD Video Wall for Control Centre (Per unit)	200000
20	Station UPS (Station UPS would require 4 hours of backup)	65000-85000
21	Camera based Bus Surveillance System	75000-100000
22	Pole based Entry/Exit Smart Card Validator for Feeder Bus	55000-75000
	Software	
23	AFCS Software	25000000-40000000
24	AVLS Software	7500000-15000000
25	Financial Management System	7500000-15000000
26	Depot Management System	2500000-4500000
27	PIS Management System	7500000-10000000
28	Vehicle Scheduling & Dispatch System	3500000-6500000
29	Software for Control Centre Hardware including video wall, servers, lan/wan equipments etc (Please provide detailed bill of quantities)	10000000-20000000
30	Handheld terminals for Ticket Inspection- software component (per license)	3000-5000
31	Station card validator for access barriers to be installed on flap barrier/turnstiles –Per license	20000-35000
32	Station Ticket Terminal (POS) with Cash Till- Software Component - per license	3000-5000
33	Bulk Initialization Machine	200000-300000
34	Card Personalization Device	200000-300000
35	Station Server- Software Component	8000-15000
36	Web Portal	3000000-4500000
37	Incident Management System	2000000-3000000
38	Business Intelligence Software with ten user licenses	7500000-12500000
39	Enterprise Management System	7500000-12500000
	Operations & Maintenance	
	Average 10-12% on hardware equipment annually	
	Average 10-18% on Software equipment annually	

NOTE: These prices have been derived from ITS contracts awarded in some cities in India and should be taken only for guidance purposes only. The cost of equipments and software in ITS industry tend

to decrease with wider market availability and are also subject to international exchange rate fluctuations.

IMPORANT NOTE:

The costs mentioned above may look prohibitive for smaller organizations and hence the organizations should look at alternative solutions like cloud hosted models to decrease capex requirements and explore opportunities on opex models. The cities could also explore cluster based solution by collaborating with nearby cities and explore implementing collaborative control centres to reduce common cost with respect to central systems. One of a good method to reduce cost on electronic fare collective could be to engage with financial institution like banks to deliver electronic ticket solutions.

4.3 Implementation Phase

The implementation phase includes procurement, installation, configuration, testing, commissioning, training, and go-Live state. This stage requires close coordination between implementing organizations, managers and service providers and monitoring of the various functions defined in planning and design phase. Since at this stage, the actual implementation of the ITS takes place, it is important to involve the core group of stakeholders that could aid in smooth and effective implementation and operations management.

This phase would ensure technology, applications and other infrastructure implementation, functional requirements related system installations, commencement and deployment of strategic initiatives. It has four steps involved:

- Deliver the Identified system
- Installation of the system
- Deployment of the system
- Utilization of deployed ITS system

4.3.1 Deliver the identified system

Implementation of ITS system requires expertise in the transportation domain and ITS. For first-time implementers of ITS, attempting to do it all in-house is a very high-risk strategy with major cost and time impact if failure to procure the right type of applications/systems as per the requirements. Therefore, it is strongly recommended to involve independent consultants to support the ITS deployment who would provide in-depth knowledge on identifying opportunities and risk mitigations related to ITS.

These domain experts could be the government or specialist firms and consultants who provide their experience sharing benefits and have no vested interest in either the technology choice or the resulting contracts; and experts from transport authorities or operators in other cities or countries. This expertise can also be supplemented by partnering with transport operators or cities who have successfully implemented similar ITS.

In order to engage these consultants, the bidding documents are prepared detailing the specifications of the ITS systems expected to be implemented. The focus of the bidding documents is mainly on the functional specifications as to what the system should perform rather than the technical specifications like how the system should perform since the technical specifications are proposed by the bidding consultant based on their skills and domain knowledge in sync with the expected ITS systems functional requirement of the implementing organization.

The subject matter experts understand ITS technology better than the implementing organization and they can envisage the solutions to best meet the requirements. They are more familiar with advancements and emerging trends in technologies. Perhaps more importantly, they will have already provided similar applications or devices for other clients. The procurement of ITS involves two stages, first stage involves initiating the bidding process where the client makes clear what its preferences are for proven or innovative technologies and the cost to functionality parameters and whether it wants a simple practical system for immediate application or a basis for future expansion. Second stage involves shortlisting the potential suppliers of ITS based on the parameters and functional requirements narrated by the client and the proposed solution provided by these bidding suppliers.

The selection criteria should be devised in advance of the procurement process, and should be carefully designed to deliver a solution that meets the Client needs. The evaluation and selection team should include relevant experts (internal and external). ITS proposal documentation is lengthy and complex. It needs to be very carefully reviewed by experts, in part to ensure that the best system is selected, in part because the technical proposal is likely to form annexes to the Contract and thus be relevant for many years.

4.3.2 Install the system in the respective working environment

Most ITS systems include devices that are installed in the vehicles, at roadside locations (e.g. in bus stops), or at public transport locations (e.g. at bus stations). This requires careful planning and advance preparation for works.

The most important aspects that are covered at this stage are engaging external consultants, engage systems integrator for multiple systems that needs to be installed to ensure efficient and effective co-ordination of these integrating ITS systems, detailed architectural plan for buses, bus stations etc. which will mandate a performance governing plan for the suppliers and finally planning the system installation activities well in advance and as per the schedule in the respective working environments.

4.3.3 Deployment of the system

ITS system deployment involves carefully planned and effectively resourced infrastructure. A comprehensive plan should cover all aspects of the deployment, and should also have contingencies for known risks associated with the ITS. A clearly defined responsibilities based ITS deployment team and capacity building including technical training and knowledge transfer is a prerequisite for effective deployment and also the logistics management like installation of the various elements of the ITS systems are the major challenges that needs to be adequately resourced and managed at this stage.

Once the planned infrastructure and processes for ITS system deployment are put in place, a formal testing regime should be established like prototype test and approvals, but in all cases it should include final product acceptance before the Client agrees to receive and pay for it. All incoming hardware and software should be formally tested prior to installation. It is advisable to install a small batch to test both the installation method and the performance of the ITS equipment/system. Once the test results are positive and the parallel run results are as expected, the ITS system should then be formally commissioned.

In parallel to the technical installation, it is also necessary to plan for and carry out training of frontline personnel, back-office system personnel, and end-users.

4.3.4 Make effective utilization of the deployed ITS system

The ITS system represents a major investment in terms of cost and time, and it is important to make the best possible use of it. Experience shows that it takes quite some time for transport organizations to fully embed the ITS within their organization, and to fully appreciate how to make the best use of it.

Making best use of a new ITS system usually takes place over three phases:

- **Initial Install Phase:** This ensures that the system works reliably, is optimized, and gains credibility with the various users and the phase continues for 1-2 years. This phase involves a lot of error correction activities and fine-tuning the implemented solution based on experience of actual use.

- **Improvisation Phase:** The transport entity(s) begins to develop, how it uses the ITS system and the information that it generates. New operational strategies will be developed and tested, usually after 2nd year of implementation. The operations data will be used to improve schedules. Enhanced analysis and reporting will be performed. Other departments will start to use the data. They will automate the inputs or data transfer to save cost and time and eliminate errors.

- **Enhancement Phase:** The third phase usually occurs after 2-3 years of operation when the transport entity has gained experience, and understands how it can build on the original system. This can include extended functionality, additional technologies, or even new ITS sub-systems

ITS users should be aware that their ITS equipment and software often includes or can support more functionality that they had specified. ITS suppliers develop their products to meet the needs of a range of customers. It is usually easier to include all basic features, or at least their interfaces, than to remove everything the Client did not ask for (which risks errors and instability). As a result, Clients often find that they can harness these additional features at little or no extra costs.

4.4 Evaluation Phase

Once the prerequisites mentioned in implementation phase have been delivered, at the evaluation phase, the transport authorities determine the effectiveness of implemented system against the strategic goals defined under planning phase.

This phase would provide inputs related to pre-implementation criteria to be considered, post-implementation monitoring criteria and evaluation criteria for any modifications or improvements in the implemented systems. The following three steps are to be covered at this phase:

- Pre-implementation checklist and criteria
- Post-implementation monitoring matrices
- Evaluation matrices for goals and improvements

4.4.1 Establishment of performance criteria

A large portion of the work done by ITS consultants actually focuses on regular performance monitoring of the implemented ITS system to ensure that everything is working as it should. ITS systems are implemented to improve performance, to allow new services to be provided to customers, to strengthen organizational capacity, etc.

Therefore, it is essential to know whether the expected improvements have actually been achieved. If the actual performance is below expectation, it may be possible to adjust or adapt the system. However, many organizations fail to measure this properly, and as a result they fail to get the properly functioning system that they envisaged before.

At this stage, the stakeholders needs to define and adopt adequate and suitable performance criteria well in advance of deployment, ideally at the design stage. The performance of the pre-ITS transport system should be monitored to provide a benchmark, and then the same criteria should be monitored post deployment so that effective functioning parameters of the deployed system can be measured.

The most important criteria for an effective ITS evaluation criteria are listed below:

- The evaluation should be transparent and allow for simple updating of impact parameters.
- The methodology should provide an accurate output, as well as being objective without any positive or negative bias.
- The methodology should allow comparison of results of evaluation of ITS and conventional transport projects.
- The evaluation should include rigorous sensitivity testing and not apply false precision to the estimated impacts.
- The methodology should consider the combined effect of implementing various combinations of ITS.
- The methodology must be developed to avoid double counting of benefits.
- The base and project cases studied in the evaluation must be based on the same operational conditions.

4.4.2 Monitoring

Once the effective performance criteria are identified and followed, the proper monitoring of performance of ITS application., performance of targeted transport functions and their impact on other transport functions becomes pivotal.

The performance monitoring parameters needs to be direct, objective, adequate, quantitative, practical and reliable and consists of three main activities:

- Measuring technical performance against the technical and functional specification – i.e. has the supplier delivered the ITS system as per the contractual obligations.
- Measuring effectiveness of the ITS in achieving the targeted functions in terms of the agreed upon criteria – i.e. does the ITS system help the organizational and operational units to achieve the objectives enunciated in pre-implementation.
- Determining both positive and negative impacts on functions which were not part of the original project scope

4.4.3 Evaluation

Once the monitoring indicators are defined and formulated, next step is to evaluate the performance of implemented ITS systems along with changes in targeted functions and its impact on the other transport factors. It involves comparing the planned projections with the actual results and optimizing the results into future ITS planning for improved efficiency and effectiveness. There is a significant investment involved, in the form both of capital investment and of organizational commitment.

As ITS generally has a high electronics and communications content, there is a large amount of technological risk. The application may be subject to technical failure and must remain flexible to future innovations in technology. As a result of the lack of experience with ITS systems and knowledge of costs and benefits, there are potential variances in the projected benefits and costs of the project. Due to the greater risk and shorter life of ITS systems, the evaluation process must incorporate extensive risk and sensitivity analysis.

It is strongly advised to carry out a formal evaluation for three main reasons:

- To verify if the expected value of the investment has been realized, and in which areas the benefits exceeded or were below expectations
- To help decisions about future ITS investments
- To learn lessons about the requirements, design, procurement, deployment and utilization, and how these can be improved in the future

The most frequently cited impacts that should be included in ITS evaluation include:

- safety impacts (accidents)
- journey time
- delay time
- modal change
- emissions and noise
- technical risk
- Vehicle operating costs etc.

It is noted that very few transport entities actually carry out a comprehensive evaluation of their ITS deployments. This is rather short-sighted, since they will inevitably come back to the decision-takers with proposals for future investments – either for additional ITS or to replace their existing systems. If they have not documented the benefits of the first investments, it could be more difficult to gain support for future investments.

Chapter 5

5 ITS APPLICATIONS

This section describes functional part of ITS systems and describes what ITS systems operate. Some of the ITS applications are not specific to a particular technical platform. E.g. Revenue management could not only be delivered on advanced technology and communication platform but could equally be delivered on a low-cost technology or platform as well. Though the benefits from ITS applications on a low-cost technology are far less in terms of all the functionalities that are advanced or higher end technology might deliver to the stakeholders but the broad functions, mode of use and data may be still comparable.

This section presents the main ITS applications that are currently in use in Urban Public Transport. The focus is on ITS used for public transport and BRT services, although many of the applications are also used in similar manner by other mode of transports as well.

Technology and Process Selection flow

ITS implementation and its applicability and ultimate benefits largely depend on the efficiency requirements of a particular organization. The organizations should carefully examine their size, fund availability and system requirements to choose particular ITS intervention requirement. The organizations should introspect well before finalizing particular areas of intervention against following criteria's:

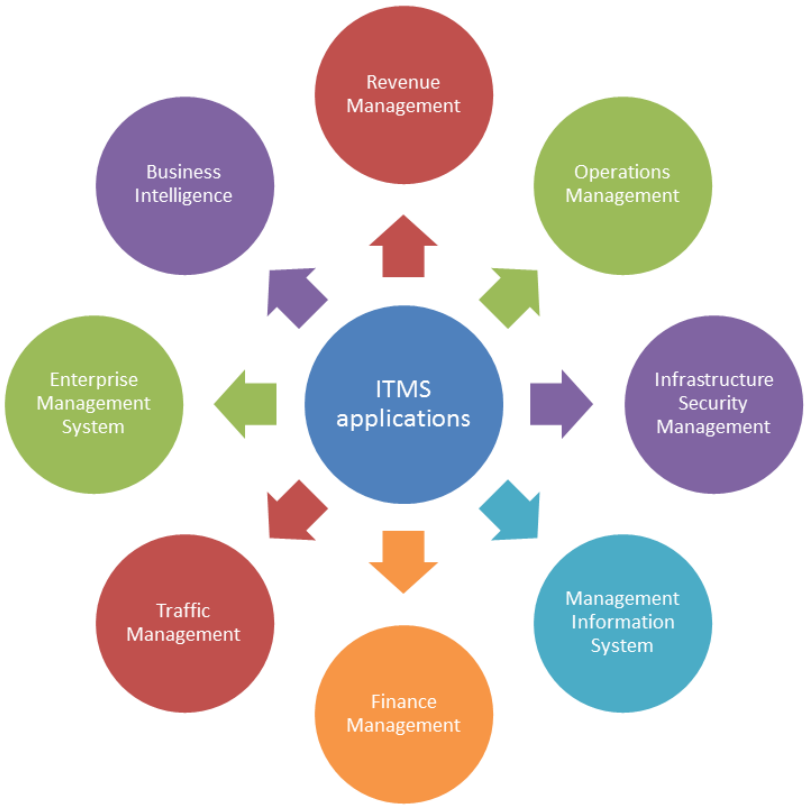
1. Size of the operations
2. Immediate intervention requirement for efficiency enhancement
3. Funding availability and sustainable sources
4. Organizational maturing and capacity

Organizations willing to go down the path with ITS implementation should pragmatically evaluate above four criteria's to determine suitability of intervention requirement alongside the timeline / phases for the same, in-case the organization decides to go for a staged process of ITS implementation.

There are eight application clusters that are discussed in this section as listed below:

- Revenue Management
- Operations Management
- Infrastructure Security Management
- Management Information System
- Business Intelligence

- Finance Management
- Traffic Management
- Enterprise Management System



5.1 Revenue Management

Revenue management refers to ability to manage revenue system of the public transport system using ITS enabled processes and technologies. The system also provides ability to manage revenue thus accrued from the PT system for the purposes of disbursals to the respective service providers.

While investigating opportunity to enhance capability around revenue management, organizations need to clearly articulate organizational and consumer needs in terms of introducing newer ways of revenue management process which revolve around ticking systems and thereby understanding operating environment like single system or multi-modal scenario. First step in this case should be to look at migrating from manual process to an electronic process and then to electronic ticket collateral like smart card, smart apps etc. once the decision is reached upon with regards to ticketing process, the organizations would then suitably pick technology to manage different service types like onboard ticketing processes, off-board ticketing process or hybrid. In most of the Indian cities off-board ticketing process may be largely seen, however cities which have closed system transportation system like BRT should focus on hybrid model which would allow them to integrate the revenue process. Essentially following ITS elements should be required for implementation of revenue management process:

On-board System:

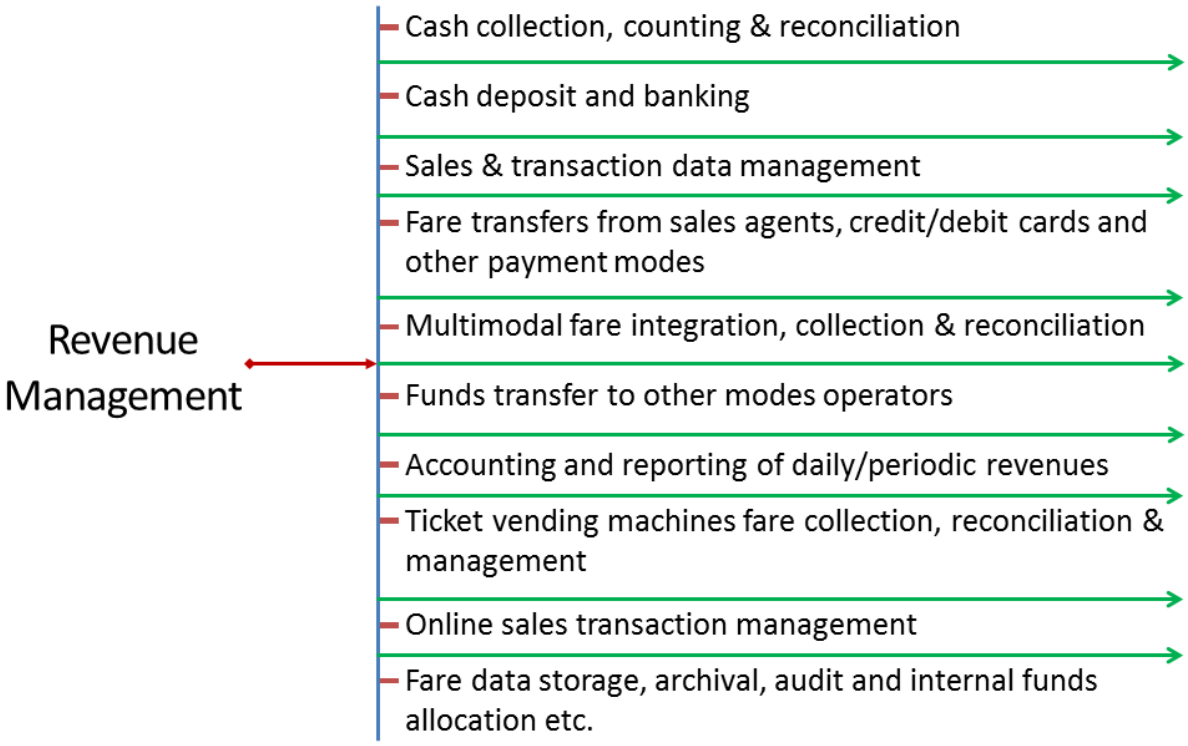
- Handheld based Ticketing Terminals
- On-board Smart Card Validators
- On-board Communication System
- Smart Cards / Electronic ID tickets

Off-board System:

- Point of Sale System
- Access Barriers
- Ticket Validators on access barriers

In both cases central revenue management system shall be required to centrally manage revenue and policies around revenue process of the organization.

Revenue management is downstream process of data generated by the ITS systems. It consists of some or all of the functions:



The data requirements for revenue accounting and distribution are primarily:

- Sales and usage transaction data from the Fare Collection System, including from in-vehicle and at-station ticket issuing machines and card readers, from sales outlets and kiosks, from 3rd party agents and fare product resellers, and from online transaction providers
- Sales and usage transaction data from non-ITS sources
- Customer and card data bases

5.2 Operations Management

Operations management is a very critical function and hence to offer system wide efficiency and efficient consumer facing applications, the organizations should carefully examine ITS requirements to meet operations management objectives. Operations management system allows organizations to view operational state of the system in real-time and hence offers ability to manage the same with reference to the desired outcomes. Essentially for a closed or open system the operations management system behaves in a common way and hence technology selection should be based on the desired functions to be delivered via implementation of operations management system.

Operations management system manages the control center operations such as:

- Vehicle scheduling and dispatch
- Dynamic rescheduling & dispatch
- Route condition monitoring
- Passenger information services
- Real-time vehicle monitoring
- Incidence and Emergency/incident management
- Schedule adherence
- Service contract compliance
- Driving standards compliance and
- Record all departures for administration, analysis, planning & intervention measures.

Transport operators based in Operations Control Centers or at depots can intervene as required to ensure that the planned service is performed, and to respond to disruptions or incidents. Transport Authorities can also use the information to monitor the daily performance. In real-time, they can direct the Operators to carry out corrective measures, or the Authority can intervene directly.

5.3 Infrastructure Security Management

While mobility and safety are the primary objectives of any good transportation system, security has also become an equally important consideration in their design and operation. A comprehensive framework of techniques to leverage ITS in support of security and safety for surface transportation infrastructure is a prerequisite for Urban Transportation facility.

Transportation infrastructure security includes the monitoring of transportation infrastructure for potential threats using sensors and surveillance equipment. Threats to infrastructure can result from acts of nature (e.g., hurricanes, earthquakes), terrorist attacks or other incidents causing damage to the infrastructure. Barrier and safeguard systems are used to preclude an incident, control access during and after an incident or mitigate impact of an incident.

It is necessary to consider the diverse aspects of transportation infrastructure security as well as how ITS can reduce risks and be protected from threats against computing environment and multi-modal transportation systems and performing risk analysis for the same. The IT Security system offers multi-tier security to the ITS infrastructure and ensures that the operations are conducted in a secure manner. IT security is a comprehensive security framework that is implemented to ensure hardware,

software, network and data is protected from any willful intrusion and the operations environment is operating under safe conditions.

It guides the stakeholders in mitigating the risks against hardware security, network and communications security, software security and logical security. The system can offer an overall security strategy which could be looked at various levels as following:

- Device Level Security via SAM's
- Application Level Security via role management and ID management
- Network level Security via VPN and associated techniques

5.4 Management Information System (MIS)

MIS is data collected for the monitoring and reporting of the business in general. It can be measured and compared against previously collected data to provide Performance Indicators of how the business is running.

Data collected through ITS applications can be a very useful resource for the transportation system with regard to variety of performance measures and is a pre-requisite for driving Business Intelligence. In addition to supporting ITS implementations, these data can also assist transportation planning, research and safety management. The MIS reports typically present actual performance against targets, highlight variances and below-target performance, provide trend analysis, and present year-on-year performance apart from advanced analytics like What-If Scenario and efficiency improvement area identification processes.

Within urban transport systems, MIS focus on:

- Financial performance
- Cost drivers
- Ridership and revenue performance
- Allocated efficiency
- Productivity of assets and human resources
- Operational performance and quality
- Safety performance
- Customer satisfaction

5.5 Business Intelligence (BI)

Providing the sixth sense needed for the business. Business Intelligence services provide the detailed reports and an at-a-glance dashboard for quick analysis visibility into the performances based on various measuring parameters in real time.

It is a set of architecture and technologies that transform raw data into meaningful and useful information for business analysis proposes and to enable more effective strategic, tactical, and operational insights and decision-making for further enhancement of the public transportation services. The system enables visual representation of critical decision data and also enables deep dive into the operational characteristics and data.

BI platform enables building reports from operations data to perform multi-dimensional analysis enabling to have better insight into parameters and enable transit managers to take business decisions leading to higher operational efficiency. BI ideally helps in developing key performance areas and the same are then automatically measured by BI tools and delivered in a manner that can aid quick decision making, e.g.: summarized information on maximum number of commuters on various routes helps decision-makers in deciding on which routes to provide with increased frequency and bus services on those routes etc.

BI tools gather the available information within the organization and present it in formats that support performance review, problem-identification and decision-taking.

5.6 Financial Management

Financial management has special significance in ITS and comprises of Receivables & payment management, financial performance management systems and Central clearing systems in case of multi-modal operations environment.

Financial management for ITS in public transportation services is to streamline & integrate finance processes, enhance cash flow & profitability from various ITS systems and better manage the financial transactions in multimodal operating environment.

Financial management system automates revenue and payment systems within the organization and brings in a critical linkage between the operations team and the finance team within the organization. The financial management system can be automated to link with service levels within contracts system and hence brings transparency and accountability within the system.

The common COTS products available in the market to achieve above mentioned functionality are Microsoft Dynamics, Tally ERP, SAP, Oracle e-business etc.

5.7 Transit Management for Public Transport Vehicles

ITS brings ability to manage traffic through monitoring, surveillance and signal management. ITS delivers public transportation and BRT services ability to surpass the congested traffic conditions; and provides ability to assign priority for bus services at traffic signals at the earliest safe opportunity. This not only improves the journey time for the commuters but also increases reliability of the bus services.

The ITS systems of the Public Transport Operator or Authority ('transit system') can interface with the Traffic Control Systems of the Traffic Authority ('traffic system'). Such interfaces:

- allow one or both systems to access information that their own systems do not provide
- allow one of both systems to supplement their own information with additional detail
- support combined services

Traffic management element consists of Control Center Operations for:

- Traffic junction and signal management for coordinated transit flow

- Traffic signal priority and network planning
- Access Control for bus services to restricted zones
- Interface with adaptive traffic control systems
- Public transport lane/facility violation monitoring

5.8 Enterprise Management System (EMS)

Enterprise Management System provides end-to-end, comprehensive, modular and integrated management of IT infrastructure components to maximize the availability of IT services and SLA performance. The management system needs to aggregate events and performance information from the domain managers and tie them to service definitions.

The tools automatically document problems and interruptions for various IT services offered and integrate with the service level management system for reporting on service level agreements (SLAs). The solutions are unified and also generate a comprehensive view of a service with real-time visibility into service status and identify the root cause of various infrastructure problems as well as prioritize resources based on impact.

The EMS encompasses the significant components of the core ITS applications. It manages the fare management services, financial management services, Passenger information services, Vehicle monitoring services, depot management, incident and inventory management services, communication services and infrastructure security management along with the information dissemination through Business Intelligent platforms.

The EMS solution consists of the following core components:

- Network Fault Management System

Integrated Performance Management System Application Performance Management System

EMS system implementation ensures that the services levels that have been agreed upon between the organization and service provider are continually monitored and linked to the payments and contracts system. The system also ensures that the operations team monitors all the functions related to network, appliances and applications to ensure there are no faults and the system works with desired operational state. The common functions provided by an EMS system are that of network state monitoring in terms of bandwidth availability, network appliance desired functionality, optimal bandwidth availability etc. The system also ensures application performance and desired operations state of the integrated network are in line with the expectations as required by the operations. The system ensures business continuity and reliability of the services.

Some of the common EMS COTS systems available in the market are: CA eHealth & Spectrum, IBM/Tivoli Business Service Manager and Service Level Advisor, BMC Remedy ITSM and Atrium, Hewlett-Packard Automation, ScienceLogic EM7

Chapter 6

6 ITS TECHNOLOGIES

This section describes the devices, software and platform specifications that needs to be considered to deliver the ITS applications. The ITS Technologies consist of a wide range of physical devices, their embedded software, and their means of communication and integration with other applications. They are the means of implementing the ITS Applications.

The information, communications and hardware/software applications are the prerequisites for ITS Technologies to perform operational, management and safety functions in line with the strategic goals of ITS implementation for public transportation. The technologies world-wide are ever changing with improved processing power, enhanced memory and storage capacity and additional functionalities to add to the enhanced commuters travel experience.

Although there are known benefits of rapid technology advancements, it poses challenges to decision/policy makers and operations whether to follow the existing technologies that are successfully tried and trusted or to risk on embracing innovative approaches in technologies thereby actively seeking opportunities for new functions and services with lower cost options. The best way/principles to decide on technology options to follow is to monitor the national/international case studies for ITS practices followed & engage solution providers to become informed and when considering the innovative technologies, verify the suppliers claims made by the suppliers (i.e. Check the sites that have already deployed) and if the new technology seems to be a risky proposition then decide on the best technology decision to make since poor performance and non-reliability may affect the overall goal of ITS implementation.

The toolkit assumes that the planning of the form factor of the system has been determined considering the following:

- Transport Plan
- Service requirements
- System funding and revenue sources
- Institutional framework
- Outsourcing Initiatives
- Network and modal planning
- Service planning and specification
- Service contracting and management
- Fares policy and practice

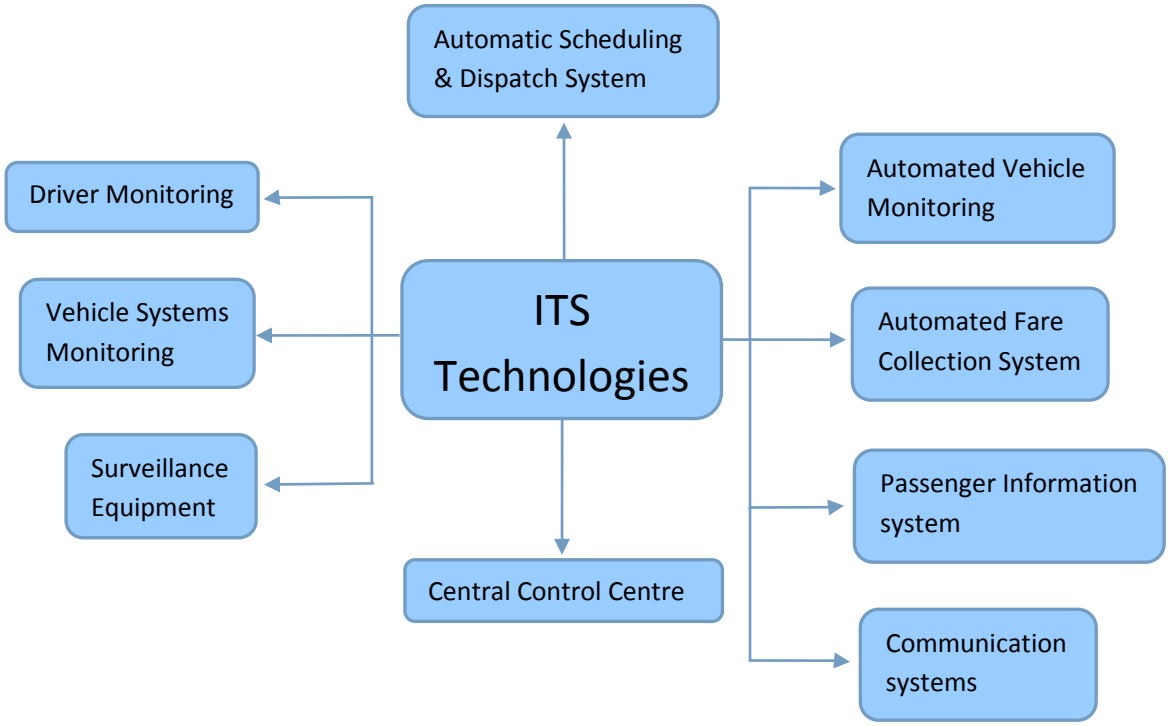
In order for an ITS initiative to meet above stated objectives of urban transport plan, the requirement shall be to understand areas of intervention which could be managed using ITS system.

For the purpose of simplification, ITS requirements have been categorized based on the functional deliverables; however the system works in a collaborative manner to deliver integrated experience.

In-order for ITS to deliver optimized operations management experience to the transport system, it's important to determine level of automation requirement at different operational area levels.

Broadly the transport ITS technologies are divided into following technical groups:

- Automated Vehicle Monitoring
- Automated Fare Collection System
- Passenger Information System
- Communication Systems
- Driver monitoring
- Vehicle Systems Monitoring
- Surveillance Equipment
- Automatic scheduling and dispatch system
- Central Control Centre



The sections below describe each of these ITS technology prerequisite to consider for public transport system:

Functional Area	Process Delivery Functions	Devices
Automated Vehicle Monitoring	• Automatic Vehicle Location System (AVLS) • Automated Scheduling and Dispatch System • Vehicle Identification	• On-board Integrated Controller • RFID Subsystem • Driver Management Console
Automated Fare Collection System	• Fare media • Devices to read/write media • Depot/station computers • Back office systems • Central clearing house	• Ticket office terminals • Ticket vending machines • Fare gate • Stand-alone validator • On-vehicle validator • Inspector/conductor device
Passenger Information System	• Vehicle mounted devices • Station Display Devices • Mobile / Web Apps	• LED/LCD Displays • Mobile Devices
Communication Systems	• Vehicle to Control Center • Station to Control Centre • Depots to Control Centre • Terminal to Control Centre	• Private radio networks Cellular • Wi-Fi • Infrared • Emerging technologies • Networking hardware
Driver monitoring	• Speed Monitoring • Acceleration • Driving Time • Braking • Efficiency	• GPS • Accelerometer • Fuel Meter
Vehicle Systems Monitoring	• Vehicle Health Monitoring • Communication to Operations Centre	• Vehicle electrical system powered through multiplexing nodes • Vehicle safety and performance features • Engine and

Functional Area	Process Delivery Functions	Devices
		transmission
Surveillance Equipment	• Station Surveillance • Bus Surveillance • Control Centre Surveillance • Other Support Infrastructure	• Fixed video cameras • Remote controlled video cameras • Digital Video recorder
Automatic scheduling and dispatch system	• Dynamic routing and scheduling of vehicles • Real time distribution scheduling • Efficient fleet and driver usage • Real time optimization based on operational constraints and business objectives • Real time planning response • Advanced warning	Scheduling and Planning System
Central Control Centre	• Application Hosting Infrastructure • Software Applications • Communications Backbone • Security Infrastructure • Service monitoring Equipment's • Network Monitoring and Management Services • Equipment and applications maintenance • Customer Contact Centre • Web Portal	• Data Centre • Communication Equipment's • Storage • Tracking Terminals • Fare Media Management terminals
	•	•

6.1 Automated Vehicle Monitoring

The Automatic Vehicle monitoring group has 3 technology components involved:

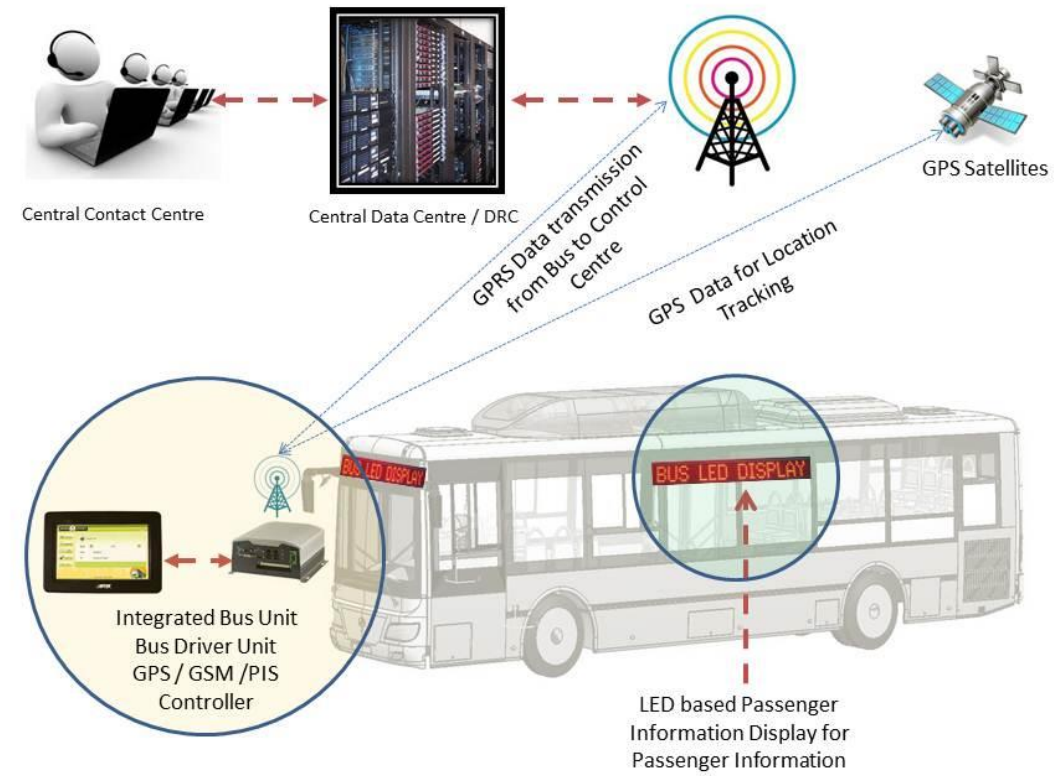
1. Automatic Vehicle Location System (AVLS)

2. Automated Scheduling and Dispatch System

3. Vehicle Identification

6.1.1 Automated Vehicle Location System (AVLS)

The AVLS system enables operations team to monitor vehicle movement in real-time and synthesize the AVL field data to deliver the same on the public information system devices installed on Bus stations, Terminals, Buses, customer portal and mobile information delivery system.



The Automated Vehicle Location System (AVLS) primarily uses GPS / GPRS devices mounted on the vehicle as primary source of data for tracking purposes. This GPS receiver can be a embedded process in other devices such as the on-board integrated computer. The GPS data contains information relating to the location of the vehicle and the time at which the signal was sent. The GPS receiver compares the time the satellite signal was received to the time that it was sent, to determine the receiver distance from that satellite. By calculating this distance for a minimum of three satellites, the receiver position can be found. Newer satellite systems like indigenously developed Gagan by ISRO promise to deliver higher levels of accuracy.

The AVLS also facilitates Central Control Centre to enable public information system to act as a source of information to be displayed on the public display screens and voice based information. The software should have capability to have a multi-screen based tracking system, so as to enable tracking staff to quickly analyze activities and have a better insight into operational data of all activities within the system. The Software can be web based and utilizes high resolution digital map to show real-time position of the vehicles. The software can provide map based tracking and transit

route line based tracking of vehicles by the city operation center operators. The software is expected to have enterprise capabilities which enables multiple user type to be enabled to carry out various functions like, Alarm Management, Vehicle Schedule Tracking, Speed Management, Stoppage management, Route replays, bus tracking dashboard etc. as a standard functionality.

The AVLS essentially comprise of following components:

- Bus Mounted GPS based driver console
- GIS Based Fleet Monitoring and Control System

Single Control Unit (SCU) transmits raw GPS data ,of vehicle locations, in NMEA protocol, to back office control center at user configurable frequency (5 seconds or less),via 3G(GSM)/GPRS, for further processing and use ,including that for signs on bus stops ,BRTS and bus terminals.

Some of the desired outputs from AVLS systems are as following:

The system as a minimum should deliver capability to generate following reports:

a. Conductor / Driver Login reports for Day, week, month
b. Non Compliance issues of different driver / conductors for the shift
c. Trip summary.
d. Bus Equipment Fault Summary
e. Hourly Bus Usage Summary
f. Bus Service Disruption
g. Passenger KMS analysis per trip configurable by the user
h. Bus Equipment Transactions
i. Bus Faults Per Transactions Processed By Device
j. Bus Equipment Fault Summary
k. Half-Hourly Bus Usage Summary
l. Summary Of Bus Passengers Boarding By Service Number

Additionally performance identification is focus area in public transport systems and hence AVLS system should specifically provide decision capable outputs to measure the same:

On Time Performance

- Scheduled KM by trip versus Actual KM by trip and Summary for day

  The report will have scheduled kilometers against actual kilometer by trip and by day. When multiple routes are operational, this information will be needed per individual route as well. The report should generate missed trips or missed kilometers per individual routes.
- On Time Performance (OTP) for Individual Trip

  System and trip on time performance report for individual routes and feeder routes.

- Daily peak, base and evening performance OTP
- Cumulative daily performance OTP
- Weekdays and weekend performance OTP
- Waiting time of bus at the junction and time to clear the junction during off peak, medium peak and peak hours.
- Speed of a bus between stations

Speed violation

The information listed above enables systems to be operated in a designated manner and also enables delivery of accurate ETA to commuters through different delivery channels.

Please refer to ITS chapter of Urban Bus Specification – II for detailed specifications.

6.1.2 Automated Scheduling and Dispatch System

Scheduling/dispatch software can be used to aid designing and modifying transit routes. It can also be used to create / activate route, schedule, and dispatch vehicles in demand response operations. The application combines GIS and AVL to coordinate different transit functions. Combined technologies such as, computer-aided dispatching and AVL increases the efficiency of transit operations, enhance safety, improve service. For example, systems integrating automated scheduling and dispatching and AVL enable a dispatcher to know the exact location and status of each bus under control. This real-time information allows the dispatcher to address any problems with service or to respond to any emergency. In addition, automated dispatching software and AVL allows the coordination of services among many separate transportation agencies.

Vehicle scheduling and dispatching system needs to be capable of dynamic planning and Capable of optimizing 1000s of vehicle movements, the system should be capable of automatic dispatch distribution and transport operations, dynamically rescheduling vehicle and driver assignments based on real-time events. Scheduling software allows a transit agency to design bus routes, create bus stops, schedule bus routes, combine individual bus trips into blocks, cut blocks into pieces that individual drivers will operate, on a daily basis assign individual drivers into runs, and provide customer information about the network. The automation allows for schedulers and transit planners to quickly develop many different scheduling scenarios rather than rely on just one, which has significantly, increased the operational efficiency of today's transit systems.

Real-time Scheduling Systems & Dynamic Planning Software benefits:

- Dynamic routing and scheduling of vehicles (including dynamic scheduling of multi-drops or multi-collects and dynamic assignment of work to resources)
- Real time distribution scheduling (last minute orders, variable demand, etc.)
- Efficient fleet and driver usage, taking account of working time directives, shift scheduling, vehicle maintenance scheduling and customer constraints
- Reduced spot-scheduling costs and better utilization of own-fleet
- Improved service levels, including better adherence to schedule and greater flexibility

- Real time optimization based on operational constraints and business objectives
- Improved visibility at all levels of the operation
- Real time planning in response to last minute orders, cancellations, redirections, etc.
- Advanced warning of potential delays due to traffic congestion or breakdowns, and tactical response.

In an operation where fulfillment windows are very narrow, and penalties for late operations may be substantial, the system should have ability to react quickly to operational problems such as traffic delays, breakdowns, last minute dispatches, etc. The system will allow planners to tackle this problem by re-planning optimally, thus reducing the need for over-resourcing and spot-scheduling while improving service levels. The user-friendly graphical planning interface should allow fast and effective interaction with the dispatcher & vehicle tracking system through on-screen maps, reports and editors. One of the systems is the driver's console installed in-vehicle.

The driver's console is integrated with AVLS and provides information to the driver when the vehicle is behind or ahead of schedule. It is technology which provides the driver with the vehicle location information depending on the type of systems being used in the vehicle. The console displays current route information including the route, the current and next few stops with scheduled arrival times, and the destination and arrival time.

The console is primarily used for dispatch & scheduling and schedule adherence monitoring to the operators. Scheduling/dispatch software is used to aid designing and modifying transit routes. It is also used to manage route, schedule, and dispatch vehicles in demand response operations. The applications combine GIS and AVL to coordinate different transit functions.

Combined technologies such as, computer-aided dispatching and AVL increase the efficiency of transit operations, enhance safety, improve service. For example, systems integrating automated scheduling and dispatching and AVL enable a dispatcher to know the exact location and status of each bus under control. This real-time information allows the dispatcher to address any problems with service or to respond to any emergency. In addition, automated dispatching software and AVL allows the coordination of services among many separate transportation agencies.

Scheduling and planning is a very important function within any public transport system, and should provide powerful routing, scheduling, blocking, runcutting and rostering solutions support to organisations requirement of scientifically managing planning and routing. The system should offer true flexibility, and adaptability to changes in service, work rules, ridership and the IT environment.

The scheduling and planning system generally offers:

- Route Scheduling System, to provide more efficient resource allocation, resulting in increased productivity and reduced operating costs
- Duty Allocation System (DAS), to streamlines the process of producing driver rosters, and manages the cost effective allocation of duties through the operational week
- Revenue Management tools, to enable to effectively report on profitability and organisation's key performance indicators

- Timetable Publishing tools, to enable to effortlessly present schedule information to customers and other IT systems.

Some of the COTS products available in market are from companies like Trapeze, capterra, MJC², Lumiplan etc.

6.1.3 Vehicle Identification

There are varieties of vehicle identification technologies available in the market and hence organization needs to access the need for vehicle identification and according access the suitable technology. One of the commonly used technologies is based on RFID. This technology is primarily used for access control and to provide real-time vehicle identification information. The system consists of hardware components in the form of the RFID tags, RFID readers/transmitters and a control system.

In this system RFID tags can be encoded with vehicle information which is read by an RFID reader. The RFID reader unit is generally located at the roadside or mounted on the station docking area, for example at a bus stop, or at an access point, such as a restricted access road with an electronic gate or retracting bollards. The reader unit emits a radio signal of a specific frequency, and when a recognized RFID tag comes into range the encoded information on the tag is transmitted via the radio signal to the reader in an encrypted format. The reader decodes this information using an embedded processing unit.

For e.g.: The Bus Docking and Automated Doors operation at Ahmedabad Janmarg is done through use of RFID technology. The components used in the solution are as following:

1. Low Frequency 125KHz RFID Reader at Doors
2. LF TAG on the Bus Side Glass near driver
3. RF 2.4 GHz wireless Transmitter on the bus driver for Open/Close
4. RF 2.4 GHz 4 Door Receiver at the station for door control and communication to door operator

RFID based solution has been primarily selected for automated door operations for the simple reason that the whole operation is wireless and offers operational ease. RFID TAG allows unique tagging of all buses with an electronic numbers and hence identification of the assets owned by Janmarg becomes very easy and offers security that only Janmarg assets can operated the automated door. RFID product that has been chosen allows vertical read range of 900MM which is within the tolerance limit of operating the system within the lane and if the same bus is outside the corridor, the door cannot be operated. The system also allows precision in horizontal tolerance WRT station door i.e. 400MM, which in turn means that the bus can dock on the docking station with a tolerance of 400MM forward or backward. This horizontal scanning ensures that the bus and the station door open only in-case of safe opening passage available for the passengers.

The RF Remote Switch which is installed on the driver dashboard is connected with the bus door also ensuring both the doors are controlled by driver using single open/close command.

RFID and RF switch offers a unique combination to offer most robust solution keeping in mind the tolerance limits that would be required to operate doors. RFID tagging also allows asset identification uniquely and same can be also used as a fall back mechanism in case of GPS outages, for Maintenance purposes, non-operational buses etc. The TAG shall also be used in future to identify and allow access to the buses in depots as designated for them; Janmarg could operate boom barriers using this tag based on the authorization of locations pertaining to those buses.

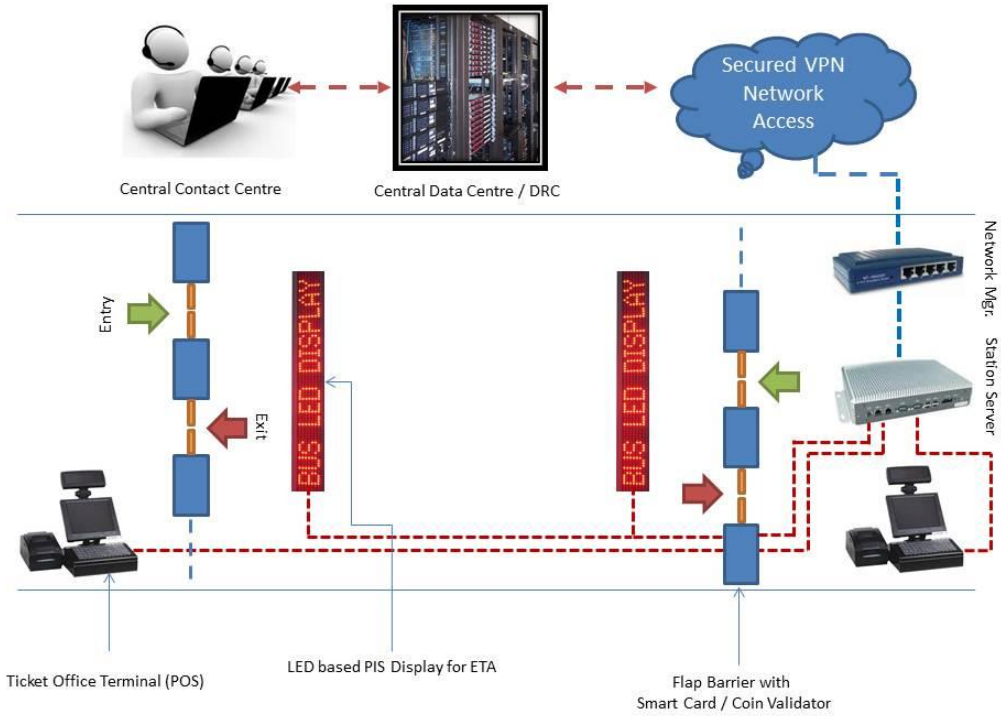
6.2 Automated Fare Collection System

An automated fare collection system is the collection of components that automate the ticketing system of a public transportation network - an automated version of manual fare collection.

AFC systems often consist of the following:

1. Fare media
2. Devices to read/write media
3. Depot/station computers
4. Back office systems
5. Central clearing house

In addition to processing electronic fare media, many AFC systems have equipment on vehicles and stations that accepts cash payment in some form.



6.2.1 Fare Media

AFC systems originated with tokens or paper tickets dispensed by staff or from self-service vending machines. These have generally been replaced with magnetic stripe cards, contact smart cards or contactless smart cards. Smart Cards are machine-readable cards which contain a microchip, store data, and can support a range of fare collection and security functions. The 'intelligence' and functionality of the smart card depend largely on the capacity of the microchip, but also on the applications stored on it. Smart cards require card loading machines to add application and value to the card and the travel is authorized through the applications loaded in onto this smartcard.

Contact smart cards connect to reader units by a direct physical connection to the conductive module on the surface of the card, whereas contactless systems interact with a reader unit using magnetic or electromagnetic field of a certain frequency which interacts with a radio antenna embedded in the card to transfer data. Contactless Smartcards typically have a range of approximately 10 cm. Smartcards do not have their own internal power source but derive their power from the card reader. In contactless systems, the card has an embedded wire loop which induces a current from the radio frequency field when it is in range of the reader, and this supplies energy to the card so that communication can occur. In contact systems, energy is derived via direct connection with the conductive pad on the surface of the card.

NOTE:

While implementing automated fare collection system, the organizations should carefully examine alternate systems used for AFCS to justify cost versus the size of the system. For example in case of a BRT system which is operating with 10-15 Kms in length and buses less than 50, the organization could choose of use turnstiles instead of flap gates, which will significantly reduce the capital cost and at the same time offer same intended services. Similarly alternate smaller form factor equipments can be evaluated to reduce the total cost of ownership.

6.2.2 Devices to Read/Write media

These take numerous forms, including:

- **Ticket office terminals -** where a media holder can purchase, a right to travel, from staff in an office, or inquire as to the value and travel rights associated with the media
- **Ticket vending machines -** where a media holder can purchase a right to travel from a self-service machine, or inquire as to the value and travel rights associated with the media
- **Fare gate -** often used in a train station so a media holder can gain access to a paid area where travel services are provided
- **Stand-alone validator -** used to confirm that the media holds an appropriate travel right, and to write the usage of the media onto the media for later verification (e.g. by a conductor/inspector). Often used in proof-of-payment systems.

- **On-vehicle validator -** used by a media holder to confirm travel rights and board a vehicle (e.g. bus, tram, train)
- **Inspector/conductor device -** used by staff such as a conductor to verify travel rights

Unattended devices are often called "validators", a term which originated with devices that would stamp a date/time onto paper tickets to provide proof of valid payment for a conductor.

6.2.3 Central Fare Management System

Servers and software to provide management and oversight of the AFC system, usually includes:

- **Fare management -** changing of fares and fare products
- **Media management -** support for blacklisting of lost/stolen media
- **Reporting -** periodic reports on performance of the AFC system, financial details and passenger movements

6.2.4 Clearing House

In environments where multiple system operators share common, interoperable media, a central system similar to those used in stock exchanges can be used to provide financial management and other services to the operators such as:

- Clearing and settling of funds
- Common reporting
- Apportionment of revenue between operators

6.3 Passenger Information System

A passenger information system (PIS) is an electronic information system which provides real-time passenger information. It may include both predictions about arrival and departure times, as well as information about the nature and causes of disruptions. It may be used both physically within a transportation hub and remotely using a web browser or mobile device.

Current operational information on service running is collected from automatic vehicle location systems (AVLS) and from control systems, including incident capture systems. AVL integrated displays have a greater functionality than standard displays. In addition to estimated arrival times for that particular service, arrival times for other services can be displayed for connecting stops which ensures that connections are not missed, thereby improving integration and customer service. This information can be compared by computers with the published service timetable to generate a prediction of how services will run in the next few minutes to hours. This may be informed by additional information: for instance, bus services will be affected by congestion on the road network, while all services may be affected by adverse weather conditions.

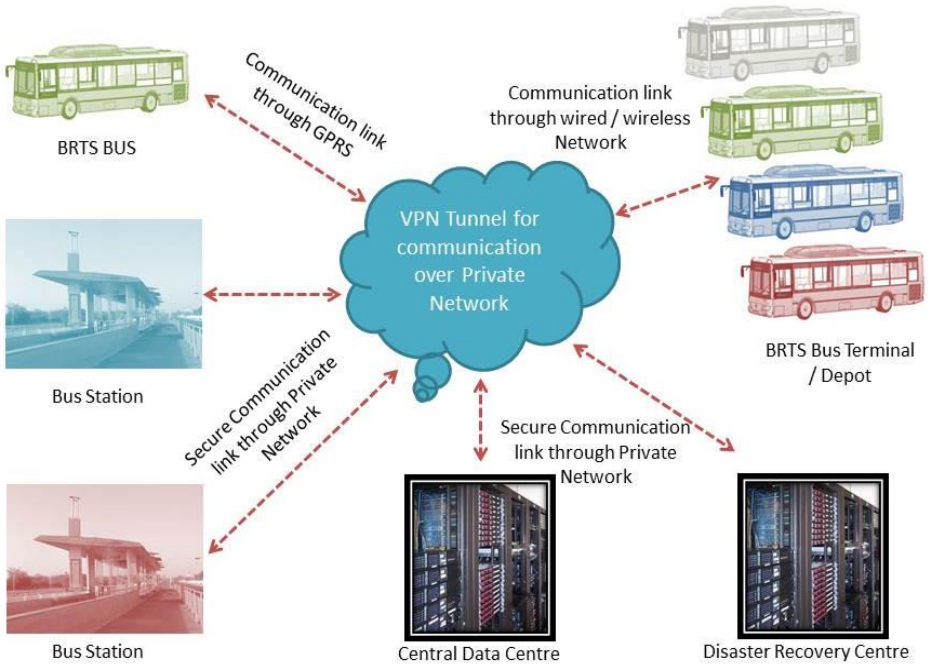
The travel information can be disseminated through - LED, LCD or plasma displays on vehicles, terminals & stops, Voice announcement systems in-vehicle or at roadside and personal display on smart-phones remotely.

There are on-vehicle display units (LED, LCD or plasma displays) which are similar to the roadside traveler information display units. LED displays units consume less power and represent lower cost, but have a lesser visual functionality and do not present additional revenue possibilities through still image and video advertising. Display types can be single function and multifunctional type display with each typically used to display essential passenger information such as route number, stop location, destination point, service connections, and as these displays can be integrated with AVL systems they can also show estimated time of arrival for particular stops and the final destination.

The in-vehicle announcement systems generally notify passengers of the next stop, available connections at stops and the destination point. There are two main types of announcement systems, pure audio systems and visual display systems with audio function. Pure audio systems are units which can be integrated with the on-board computer which links the unit to multiple systems including the vehicle doors, the AVL and radio systems. The on-board computer cross references schedule information with the AVL system and triggers the audio unit to announce the next stop as the vehicle approaches and when the doors open.

6.4 Communication System

The communication system is critical to the operations and management of ITS and should be designed carefully to ensure adequate bandwidth is provisioned for the purpose of data and application services exchange.



The CCC (Central Control Centre) requires different assets and locations to connect to the central computing environment and hence the network should be deployed in a way which offers

communication and data security via implementation of various techniques like VPN, encryption and compression tools. The various locations that connect to and fro to the CCC are DRC, bus device, bus stations, depots and terminals.

The communication needs for ITS implementation has 6 sub-groups for efficient and effective performance of the ITS services. These are: Communication between the vehicle systems, vehicle to and from control center /stop shelters/traffic signals, data transfer from the transport vehicles and between the various facilities etc.

The Controller Area Network bus technology enables communication between vehicle systems in transportation services currently. This network comprises of a system of linear network based control units with all the communication signals passing through each control unit (Node). Each of these nodes are capable of receiving and transmitting data in a message form and when these messages are transmitted, it is delivered to each node. As each node has a unique identity they can be differentiated from each other and the message is only accepted by the node for which it was intended. Each node can request access to the bus at the same time but some nodes, such as the airbag control unit, have priority over others.

Roadside detector systems allow communications between vehicles and stops which is most often related to the provision of real time information or for the transfer of automatic vehicle location information. In these roadside detector systems, the electronic sign at the roadside contains a transmitter which continuously sends a radio signal with information identifying the stop number or location. As the vehicle passes the roadside beacon, an on-board receiver picks up this transmission. The receiver is connected to the radio system, generally through the on-board computer, which transmits the vehicle position and a time-stamp of when the stop was passed to the control centre.

The utmost priority of the transportation services is the efficiency with which the commuters are able to travel to their designated destinations without significant wastage of time in travel. For this reason, the public transport services are provided priority at traffic signals. To allow this facility, operators use the technology which enables them to communicate between vehicles and traffic signals. These systems allow vehicles to operate along routes with minimal stoppages and are particularly useful in city's congested areas which often consume more travel time. A variety of systems are available to achieve signal priority, with the most common being roadside detectors and sub-surface detectors. Typically subsurface detectors, usually inductive-loop detectors, are used in situations where traffic lanes are reserved for public transport vehicles similar to BRTS in Ahmedabad. In these systems the vehicle does not communicate with the traffic signal control directly, but is sensed by the detector which then interacts with the signal control unit to request priority.

There are a number of methods of uploading and downloading information to and from vehicles including laptop connection, portable data memory modules, infrared systems and wireless LAN. The use of portable data modules, such as Smartcards, and physical connections using laptops or handheld devices have been common methods historically. Using physical connections for data transfer has a number of drawbacks, particularly in terms of additional labour requirements and vehicle downtime, whereas wireless systems overcome these problems.

The use of fiber optic cable connection is the best method for transporting data between facilities. Fiber optic connections have higher capacity and are many times faster than any other method of connection allowing for much greater amounts of data to be transferred over longer distances. These types of connection are ideally suited to intelligent transport systems which require ever increasing data carrying capacity and transfer speed.

In Summary, some of the communication technologies are:

Private radio networks: Consists of a radio base, radio towers and transmitter/receivers in each bus. Enables long-distance exchange of live data. Since the packet sizes are limited, heavy downloads can be performed but may require a considerable amount of time.

Cellular: Each bus has a cell phone for voice and a cell modem for data (can also be combined). Enables long-distance exchange of live data. Fees are calculated on the quantity of bytes transmitted. This method should be limited to live data only or extremely small packets, such as vehicle information.

Wi-Fi: Consists of a garage or an area with wireless access points. Each bus has a Wi-Fi bridge that links the bus to the network. Limited area of coverage and encryption is required to prevent hacking.

Infrared: Consists of a receiver/transmitter in the garage and a receiver/transmitter in each bus. Bus needs to be aligned to the receiver/transmitter. Limited speed of transmission.

Emerging technologies: WiMAX, a third-generation cellular technology.

Other technologies:

RFID: Identifies the location of a vehicle at a particular point on the circuit. This information is then sent to the central system by another means of communication.

Inductive loops: Similar to RFID, confirms location of a vehicle at a particular point on the circuit. This information is then sent to the central system by another means of communication.

Street-side beacons: Bus triggers a street-side beacon by short wave or another means as it passes by. This information is then sent to the central system by another means of communication

6.5 Driver Monitoring

Driver guidance service delivers important information and tools to the drivers to enable them to deliver operational efficiency and safety. This service enables drivers to monitor service related parameters and act based on the suggested parameters and also allows central control center to interact with the drivers in event of required intervention. The system delivers information like service status, vehicle health, operations guidelines etc.

One of the technology components of monitoring the driver activities is to monitor the driving hours and their rest periods. The primary reason for the monitoring of drivers hours is to control driver activity so that driver fatigue is avoided and a safe & good standard of working conditions is maintained. One of the ways through which this can be ensured is by having monitoring technologies

like surveillance and enforcement tools are implemented for e.g. Tachographs - devices that are fixed inside the cab of the vehicle that measures how long the driver is on the road and compliance with driving regulations. The device measures the distance that the vehicle has covered, the vehicle speed and driver activity in terms of breaks and rest stops, periods of availability, driving time and other work. Use of mobile networks also allows for storage of information and tracking of vehicles/transmission of data when signal is available.

Another technology element is measuring the driver's driving patterns. The objectives of measuring driving style are to reduce fuel consumption, improve road safety, reduced operational costs and to reduce emissions levels. Accelerometers are an effective tool in helping monitor driving style and in most cases are used in coordination with GPS. Accelerometers are sensors mounted on-board the vehicle and are generally connected to the on-board computer for data processing so that information can be displayed to the driver or the operations control center.

Currently, there are smartphone technologies as well which enables monitoring the real-time driving style. These smartphones use accelerometer and GPS technology to provide accurate data which can be used to interact with the driver in real-time and to track and record behavior for further analysis. This method uses in-built devices along with a software platform to present the information.

To incorporate a practice of 'Driver Score Card' using above set of technologies, few suggested parameters are as following:

I. Door Open while driving
II. Harsh Acceleration
III. Excessive Idling
IV. Harsh Braking
V. Over revving
VI. Over speeding
VII. Excessive Trip Mileage (Fuel Mileage)
VIII. Non Adherence to 'Trip Schedule' e.g. 'Late Start', 'Off Route' and 'Duty Cycle'
IX. Driving with Faults: Warning Pop ups reported and initiative to get corrected
X. Panic Button usage
XI. Cameras switched off
XII. Internal Sign Switched off

Data from the above will be based on

- VHMD Log files and SCN data downloaded at end of the day including Driver ID
- Live AVL location transmitted from Bus.

6.6 Vehicle Systems Monitoring[1]

Vehicle systems monitoring consists of tracking passenger boarding and loading, monitoring fuel usage rate, monitoring the technical Status of the vehicles.

The passenger boarding information is collated to optimize the use of resources and enable real-time service planning and route optimization. The collection of passenger boarding data allows for detailed route analysis providing information on use of specific routes or route segments at particular times of year, day of the week and time of day. A variety of technologies are currently available to detect passenger boarding and loading including treadle sensors, infrared sensors, internet protocol cameras and stereoscopic cameras.

Fuel consumption rate is also one of the critical factors to be considered when implementing ITS technologies. Technologies are predominantly used for the measurement and analysis of fuel consumption rates under a variety of operating conditions. Fuel consumption monitoring technologies can provide a means of surveillance to detect manipulation of fuel such as unauthorized draining of fuel. Monitoring devices also allow for the early detection of vehicle performance problems and the detection of excessive fuel consumption during operation. These technologies are commonly integrated with GPS devices to provide real-time vehicle tracking of fuel consumption to fleet operators and can also be used in unison with driver behavior monitoring devices. The technologies used for fuel usage rate data capture include a fuel flow meter and fuel level sensor integrated with a GPS tracking device. The measurement components are located in the fuel system and are connected to the on-board computer where data is processed in line with information from the GPS unit and transmitted to the central control center.

The vehicles engine, driveshaft, transmission and other components responsible for generating and delivering vehicle power to the road is very important to be monitored for efficient and effective utilization of the services and resources.

The specifications that can be considered for vehicle technical status are provided below:

Single Control Unit (SCU) receives vehicle health diagnostic data from multiplexing nodes and PIS signs. The data from multiplexing nodes, on a single CAN 2B(JI939) bus includes parameters from:

i. Vehicle electrical system powered through multiplexing nodes

ii. Vehicle safety and performance features

iii. Engine and transmission

'SCU' should be able to create log files and communicate to control center at end of the day via WLAN and the parameters are listed below:

1. Vehicle electrical system

All external and internal fixtures like passenger/driver compartment illumination and ITS equipment.

[1] Source: Worldbank - Toolkit on Intelligent Transport Systems for Urban Transport

2. Vehicle safety and performance features

- Fuel /Oil level/ Pressure
- Braking pedal position
- Accelerator pedal position and kick down
- Brake pad condition and brake pedal temperature (in case of electronically controlled disc brakes)
- Door interlock
- Kneeling interlock (wherever provided)
- Gas leakage detection (wherever provided)
- Fire detection/suppression (wherever provided)

3. Engine

- Engine CAN status
- Engine oil pressure,
- Engine coolant temperature,
- Engine speed in RPM,
- Vehicle speed (torque),
- Diagnostic message (engine specific)

4. Transmission

- Transmission CAN status
- Transmission output shaft speed
- Transmission input shaft speed
- Transmission current gear
- Transmission oil filter restriction switch
- Transmission oil life remaining
- Transmission service indicator
- Transmission sump oil temperature
- Transmission oil level high / low

- Hydraulic retarder oil temperature
- Accelerator pedal
- Diagnostic message (transmission specific)

5. Diesel bus electronics data

- Drivers demand of engine torque percentage
- Actual engine torque percentage
- Engine and retarder torque
- Engine speed
- Source address controlling device
- Engine starter mode
- Engine demand torque percentage
- Accelerator pedal 2 low Idle switch
- Road speed limit status
- Accelerator pedal kick down switch
- Accelerator pedal low Idle Switch
- Accelerator pedal position
- Percent load at current speed
- Remote accelerator pedal position
- Accelerator pedal position 2
- Vehicle acceleration rate limit status
- Engine temperature
- Engine coolant temperature
- Fuel temperature
- Engine oil temperature
- Turbo oil temperature
- Engine intercooler temperature
- Engine intercooler thermostat opening

- Engine fluid level pressure
- Fuel delivery pressure
- Extended crankcase blow by pressure
- Engine oil level
- Engine oil pressure
- Crankcase pressure
- Coolant pressure
- Coolant level

6. CNG bus electronics data

- Engine control unit
- Engine speed sensor
- Atmospheric pressure sensor
- Brake switch signal
- EEPROM error
- Vehicle speed sensor
- Main relay main relay
- Ignition switch
- Fuel temperature sensor
- Turbocharger boost pressure sensor
- Boost pressure control
- Accelerator pedal position sensor 1
- Accelerator pedal position sensor 2
- Analog/digital converter
- Coolant temperature sensor
- Fault lamp, engine control
- Electric shutoff (ELAB)
- Needle sensor

- Secondary engine speed signal
- engine speed sensor
- Start-of-injection control
- Injection timing solenoid valve
- Voltage supply control units
- Reference voltage
- air temperature sensor
- Control-collar travel sensor
- Control-collar travel sensor
- Test after running test
- Control-collar travel sensor
- Engine control unit
- Misfire recognition

The above parameters are generally standard part of the multiplexing system and have free flow data available from the bus electronics system. The organizations can choose to monitor all or some on basis of their service and maintenance requirements.

These tests standard compliances are common to PIS signs/multiplexing nodes/controller/driver console

Sr.No	Test Standards Compliance	Specifications
1	**Performance parametric test**	Nine points, tri temperature/tri voltage- 18V, 27V, 32V,-25°C[2], room temperature, +85°C test. At each test point the system will be powered on and shut down 5 times as per the supplier's designated procedure and thereafter evaluated for malfunction if any
2	**Cold**	IS 9000 (Part II/Sec 4)-1977 (reaffirmed 2004) at -25°C for 2 hours in 'on' condition

[2] The specifications are based on UBS II and also validated by ARAI. Since the equipment's are generally based on international test and operating standards, the ranges are also defined by product manufacturers keeping diverse geographies of operations in mind.

Sr.No	Test Standards Compliance	Specifications
3	**Dry heat**	IS 9000 (Part III/Sec 5)-1977: PIS Signs, SCU and Nodes at + 80°C for 16 hours in 'on' condition. BDC at + 80°C for 2 hours
4	**Damp heat**	IS 9000 (Part V/Sec 2)1981 at +25°C /+55°C, Humidity 95%, 24 hours for 6 cycles in off condition. Functional test with power in 'on' condition at start of 2nd, 4th and 6th cycle
5	**Vibration standard AIS 012/AIS:062 -10g**	2. Frequency 5~50Hz and return to 5Hz at a linear sweep period of 1 minute/complete sweep cycle and 10g at maximum frequency 3. Excursion -1.6 mm peak to peak over the specified frequency range 4. Test duration 60 minutes Direction of vibration –X, Y, Z axis of device as it is mounted on the vehicle
6	**Dust and water ingress protection**	IS /IEC 60947-1:2004 in conjunction with IS/IEC 60529:2001– 'PIS signs' IP66, 'SCU' IP 65, 'BDC' IP65, 'nodes' IP54
7	**Free fall**	IS 9000 (Part VII/Sec 4) Free fall at 500 mm ,(applicable to 'nodes' and 'controllers' only)
8	**Fire resistant**	6. Regulation directive 95-28/EG dated 24-10-1995 horizontal Burning rate tested as per ISO 3795 , 7. Horizontal burning test HB as per UL 94 -1998 clause 7 (for wire harness)
9	**Reverse polarity protection without fuse**	The component must fulfil the function- and service life requirements after being subjected to reversed polarity up to 27 V for 2 minutes.
10	**Over voltage protection**	To ensure service life requirements and functionality. The component shall run for 60 minutes at 38V, without effecting the service life or function

Sr.No	Test Standards Compliance	Specifications
11	**Insulation resistance**	The Insulation résistance measured as per ISO 16750-2 with a voltage of 500 V dc shall not be less than 1Mega ohm.
12	**Cranking voltage**	The components shall have an electrical energy reserve that can handle voltage drop during cranking. Component shall not reset during cranking-'FSC B'. The supply voltage during crank is 18.0 V for 40 ms. The test to be carried out as per ISO 7637
13	**Load dump test on controller**	123V ,8 Ohms 200ms pulse 5a as per standard ISO 7637-2
14	**Salt spray test**	(AIS: 012/ IS10250) 96 hours
15	**EMC/EMI**	1.Electromagnetic radiation, radiated immunity and compatibility as per AIS 004 (Part 3) or 2.72/245/EEC last amended by 2009/19/EC (includes 2004/104/EC, 2005/83/EC, 2006/96/EC) and UN ECE Regulation Number 10 Rev 3:2008 Note: In case of product is 'e' marked and a detailed test report is submitted (which includes above tests) no fresh verification is necessary
16	**Operating parameters**	Supply voltage 24 V± 25%
17	**LED color test – dominant wave length** **Amber**	AIS -012
18	**LED chromaticity coordinate**	Limit towards green: y ≤ x-0.120 Limit towards red: y ≥ 0.390 Limit towards white: y ≥ 0.790-0.670x
19	**LED bulb/SMT intensity and viewing** **angle**	In accordance with CIE 127 condition B

Diagnostic trouble codes (DTC) and Parameter Identifiers (PID) list

Appendix 1 – DTC code list of PIS signs

DTC code				Description
1	2	0	0	Over Voltage
1	2	0	1	Low Voltage
1	2	0	3	Over Heat

PID code list of PIS signs

Example of PIDs code numbers for a LED sign. PIN code is Ascii characters.

PID code	Description
100	Hardware revision
101	Serial number
102	Boot loader SW revision
103	Application SW revision
104	Font library revision
105	CPU part number
106	CPU qualification
107	CPU temperature range
108	Compilation of FW date and time
109	Flash update status
110	Test date and time
114	Article number sign level
115	Production date (production date)
116	End customer
117	Order number

PID code	Description
118	Bus/vehicle type
119	Bus builder number (bus build)
208	Language
401	Board temp sensor
402	Internal CPU temp
600	Minimum temp CPU
601	Maximum temp CPU
602	Maximum temp board
603	Minimum temp board
604	Maximum input power voltage
605	Minimum input power voltage
606	Operating hours
607	Number of resets

DTC code list of controller

DTC code				Comments
0	0	1	2	Watch dog reset
0	0	1	3	Low voltage reset
0	0	2	0	Lost communication, GPS satellite (GPS receiver is not available to the system.)
0	0	2	1	Invalid data, GPS signal invalid
0	0	2	2	GPS antenna error
0	0	2	5	USB, invalid USB mass storage device
0	0	2	6	USB, unknown USB device connected
0	0	2	7	USB, USB invalid file system
0	0	2	7	USB, overcurrent
0	2	0	0	Over voltage
0	2	0	1	Low Voltage
0	2	0	3	Over heat

PID code list controller

Example of PIDs code numbers for control unit. PIN code is Ascii characters

PID code	Description
100	Hardware revision
i.101	Serial number
102	Boot loader SW revision
103	Application SW revision
104	Font library revision
105	CPU part number
106	CPU qualification

PID code	Description
107	CPU temperature range
108	Compilation of FW date and time
110	Test date and time

6.7 Surveillance Equipment

Traveler security system offers security of passengers and crew by using video surveillance cameras. By functioning as deterrents to criminal activity and inappropriate behavior, these cameras provide passengers and drivers with an added sense of security, and can also supply valuable evidence during criminal investigations. There are many different types of CCTV systems available—analog and digital, wired and wireless—and their modes of operation vary; however, the basic components are in essence the same: a CCTV camera, a CCTV camera lens, a CCTV monitor, and (for wired systems) cables that carry the signal from one place to another.

The images collected are sent to a CCTV monitor and recorded on video tape via a VCR or as digital information via a DVR (Digital Video Recorder). The CCTV camera lens will determine how far and much detail the CCTV camera can see.

The CCTV camera picks up the signal from the area being monitored, and in a wired system, the CCTV camera sends the signals through a coaxial cable to the CCTV monitor; in wireless systems, no cable is needed, instead the CCTV camera broadcasts the signal. Monitors can be watched by CCTV controllers or left unmonitored.

Recent advances in technology and software mean many DVRs are now equipped with advanced features such as Motion Recording and Event Notification. When set to motion record devices will only record when the CCTV camera detects motion. This saves storage space because the device is not recording during periods of inactivity. Event Notification is the process of sending a text message, recorded telephone messages or email when motion is detected. This is particularly useful for unmanned systems. The recorded information can be stored and/or reviewed by those who have access to the recordings at their convenience.

The surveillance cameras could have 3 associated technologies:

- **Static video cameras** - These cameras are fixed in one position and cannot be remotely controlled. Static video surveillance systems allow service operators to monitor activity in vehicles or at stations across the whole network remotely through CCTV (Closed Circuit Television) cameras. These cameras can be either digital or analogue systems. CCTV cameras provide analogue video which is transmitted via coaxial cable to one particular location where video is recorded and monitored.

CCTV footage can be recorded in analogue format using a VCR (Video

Cassette Recorder) or in digital format using a DVR (Digital Video Recorder). CCTV system requires wiring between the cameras and the VCR or DVR unit which is usually located at a monitoring station.

- **Remote controlled video cameras** - Both CCTV and IP cameras are available with PTZ (Pan/Tilt/Zoom) functions allowing surveillance equipment operators to control systems remotely. When installed in stations or terminals, analogue PTZ systems can be advantageous because video processing is done at the monitoring station rather than on the camera, as in IP systems. Due to this, video is transferred immediately providing real-time viewing and accurate remote movement control functions.

Some camera systems are real-time video streaming control from the driver console where video surveillance systems are integrated with wireless radio equipment capable of real-time data transfer, the driver can select when to stream video to a control center via button mounted on the driver console. This may allow for reduced storage requirement if cameras are only used when requested, however this may lead to events being missed if the driver does not react fast enough

- **Digital Video recorder** - Digital video recorders allow for the continuous recording of video and are the most popular technology for recording surveillance footage. This technology has removed the need for tape cassettes and VCRs, allowing video to be recorded on a computer hard drive, memory card or USB. The role of the DVR unit is to capture analogue video from surveillance equipment, convert it to a digital format, compress and decompress video, and to record it for analysis using diagnostic software.

Large scale surveillance systems, such as those used in transport operations; require a lot of processing power to manage the quantity of footage being collected. The DVR encoder/video card is the unit component responsible for image capture, compression and decompression. This encoder card includes one or more processors which perform these functions using algorithms.

The recorded videos can be manipulated or processed further with the help of computerized image processors. The recorded videos once copied on PC hard drives, allows the operator to fast-forward and rewind video at different rates, perform zoom functions, watch video in slow motion, or view video on a frame by frame basis.

Surveillance Cameras on Buses ensure following:

Protect drivers – Bus drivers must put a lot of faith in their passengers acting appropriately. Unfortunately, one never knows what type of riders will step onto the bus on any given day. The presence of on-board security cameras can help in deterring and investigating unacceptable behavior and aggressive outbursts directed towards drivers.

Enforce rider regulations – Bus rules and regulations are easier to enforce with a second set of eyes. It's common for buses to feature signs which mention the presence of video surveillance. Riders who know they're under watch are more likely to follow rules, pay bus fares, and obey driver orders.

Prevent theft – On-board security cameras monitor bus activity, and act as preventative measure against acts of theft between riders.

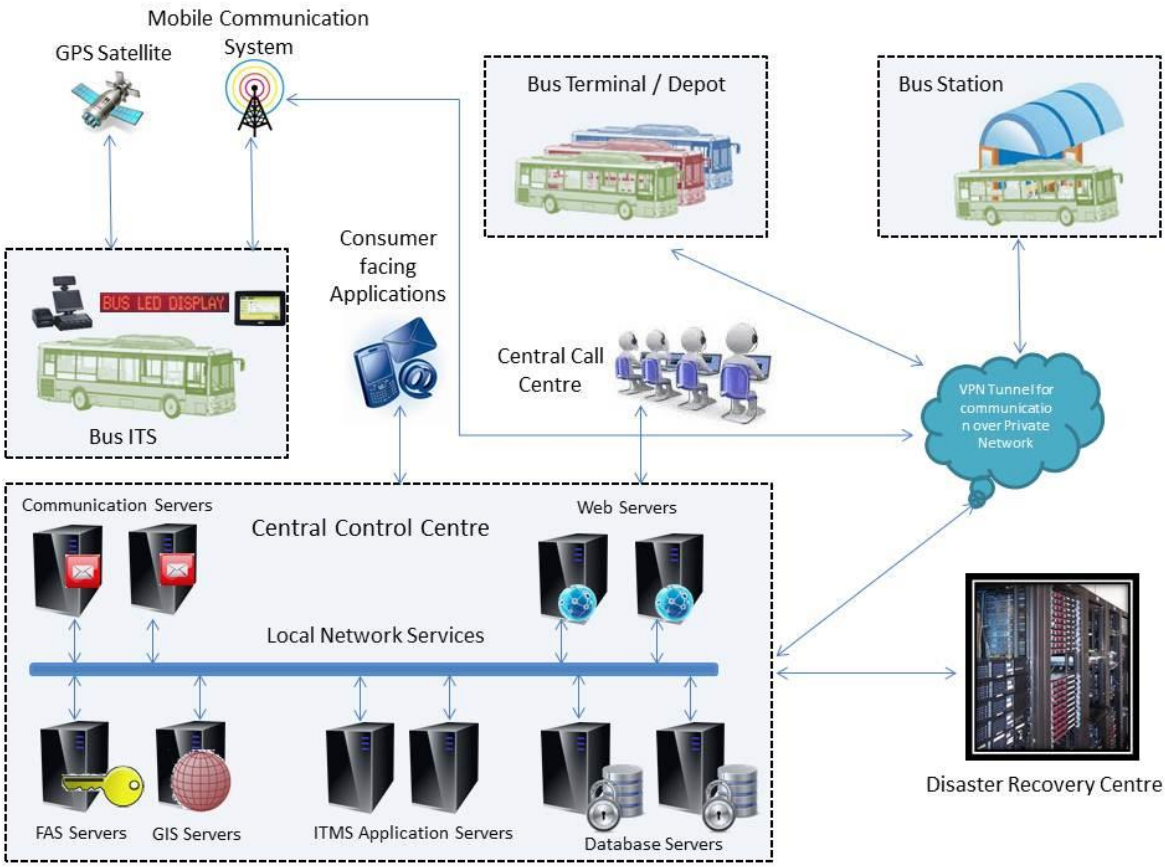
Deter violence – The unpredictable nature of bus passengers throughout the day can at times lead to violent incidents. Such an incident could stem from an argument between riders, or a passenger under the influence of alcohol or drugs losing composure. Surveillance cameras can monitor for such unsavory activity, enabling operators to alert authorities should an incident break out.

Enhance passenger safety – Users of the bus system want to be confident that their mode of transportation is a safe one. On-board video surveillance cameras give riders the assurance that authorities are doing everything in their power to provide a high level of security.

Crime investigation – Footage from on-board security cameras can prove valuable in criminal investigations of incidents taking place on buses as well as outside crimes involving specific suspects whose images may be uncovered.

6.8 Central Control Centre (CCC)

The central control center form as the nerve center for the operations management and service delivery for ITS system. The CCC offers centralized services for applications and infrastructure to drive field operations using variety of ITS tools and techniques.



The CCC predominantly has following as part of its composite offering:

1. Application Hosting Infrastructure
2. Software Applications

3. Communications Backbone
4. Security Infrastructure
5. Service monitoring Equipment's
6. Network Monitoring and Management Services
7. Equipment and applications maintenance
8. Customer Contact Centre
9. Web Portal

1. Application Hosting Infrastructure

The applications hosting infrastructure consists of computing resources like servers, storage etc. which enable the applications to be installed on them and to be used by the users and appliances within the ITS landscape. The system would include data center infrastructure like racks, precision cooling system, fire alarms and retardants, access control systems and surveillance systems.

2. Software Applications

ITS essentially offers multi-tier architecture to manage software function delivery and also generally is vendor dependent. However, as a general principle of high availability, the architecture should be defined in a way that in event of central infrastructure outage, the field devices are still in a state to offer minimum set of functionality to ensure business continuity.

The applications that form part of the installed environment at CCC are as following:

- Automated Vehicle Location System
- Automated Fare Collection System
- Passenger Information System
- Automated Scheduling and Dispatch System
- Incident Management System
- Business Intelligence System
- Enterprise Management System
- Asset Management System
- Traveler Security System
- IT Security System
- Electronic Ticket Initialization
- Finance and Accounting System
- Central Clearing House System

All the applications/technologies mentioned above although have individual functions to deliver within the scope of ITS, the applications do depend on each other for the purpose of delivering aggregate services from management's standpoint. Some of these are already discussed previously.

3. Communication Backbone

This is already discussed under 'Communication Systems' above.

4. Security Infrastructure

This is already discussed under 'Infrastructure Security Management' above.

5. Service Monitoring Equipment's

The service monitoring is a very essential function with the CCC operations and essentially comprises of two functions:

a. IT Components service monitoring
b. Operations Service Monitoring

The system offers above functions via variety of tools and infrastructure to ensure that resources positioned within CCC have ability to track activities that are important from the standpoint of service quality and continuity. Enterprise management system offers ability to monitor all the installed ITS assets including hardware, software, databases, communication links. The enterprise management system offers management capability to link information retrieved to service levels as agreed and required to ensure high availability of the system. This system also ensures that incidents are detected as soon as they occur and support services are activated based on agreed protocols of service resumption.

6. Network Monitoring and Management Services

Network monitoring and management services offer ability to the CCC to monitor and manage network operations using infrastructure covering LAN, WAN, Wired Communication links and wireless communication links. This service is critical for the real-time management of various functions with transit systems. The network infrastructure at CCC includes network switches, routers etc. connected to field devices at bus stations, buses, depots and terminals. The CCC could be connected to field device using wireless or wired communication links with an exception of buses, which use only wireless communication links. The communication can be established on buses using variety of service types like Wi-Fi, Wimax, and GSM/GPRS etc. The selection of communication links shall primarily depend on the cost, reliability and high availability of then communication system.

The network monitoring system (This system is part of enterprise management system and eventually managed through incident management system. These services are part of CCC management are deliver in conjunction with service staff.) ensures that all the communication lines are delivering guaranteed up-time and bandwidth and in-event of failure to deliver services up-to the required levels, the alerts are generated and actions are taken by the respective service providers to resolve the same.

7. Equipment and Application Maintenance

The CCC being the central operations management centre, its best positioned to offer quick service restoration services for equipment's and applications infrastructure in event of failure. Since the technical team is positioned in the CCC and the knowledge is being archived at the same location, the maintenance services are advisable to be near CCC to reduce time to service.

Operations and maintenance is a very important activity as part of the business continuity and sustenance point of view. O&M activity generally encompasses activity around people, processes and

equipment's in a predetermined manner to deliver intended results from the integrated environment.

Generally operating window of any public transport system varies from 16-20 Hrs and hence manpower planning and support services like breakdown and incident management activity should be scheduled in accordance with the operations requirements.

The typical requirement at the CCC level from manpower standpoint is that of operations team like applications, network, equipment's, activity and incident managers. The staffing should be done on the basis of peak / off-peak requirements so that at any given point in time, minimum critical service and operations staff is available to manage operations requirements.

The service provider should create preventive / predictive maintenance plans to ensure minimal outages within the system as this also ensures systems readiness at all times. The operations management has to deal with lot of operating parameters in real-time and thereby capability and capacity has to be created to manage and deliver services on basis of operations state requirements. The service providers have to ensure standard operating procedures are developed and implemented with the system to ensure that the operations are conducted in a predetermined manner and that the results are generally predictable.

8. Customer Contact Centre

Customer contact centre is a consumer facing system and is required to deliver services related to service, fare system and general functions of the transit system. The system is primarily needed to ensure proper information delivery to the commuters and also resolution of complaints related to the system. The system has to be designed based on industry standard practices of consumer service management and the system thus should be able to provide automated service management function from call logging to call closure. This system also plays an important role in ascertaining service feedback from the consumers, which forms as an important part of service standard enhancement process.

9. Web Portal & Mobile Apps

The web portal is a consumer facing application and provides consumers to avail different kind of services, which may include:

- Estimated Time of Arrival of buses
- Travel Planner
- Electronic recharges
- Service Information
- Complaints Management
- Feedback Management
- Mobile based Information System etc.

Chapter 7

7 CASE STUDIES

This section presents case studies for ITS planning that can be adopted from the cases selected from around the world to demonstrate the various aspects of Integrated ITS as mentioned in the previous section. The selection of the case studies is based on the literature review.

The scope of this literature review is to synthesize some particular ITS benefits based on real experiences in urban areas. The review by no means intends to be a comprehensive evaluation of benefits in these areas. Instead, the purpose of the report is to highlight examples under each category on the national or international level and include a synthesis of documented benefits from ITS programs.

The below mentioned cities are considered for the literature review on ITS:

1) Dublin, Ireland

2) Zurich, Switzerland

3) Izmir, Turkey

4) Ahmedabad, Gujarat

5) Curitiba, Brazil

7.1 Dublin, Ireland[3]

Overview

- Dublin Bus is the publicly-owned operator of the bus network in Dublin. It operates 980 double-deck buses in the city and hinterland of Dublin.
- The company has implemented extensive ITS over the course of two decades. Electronic Ticket Machines were first implemented in 1989 and have provided the backbone of the on-bus intelligent network.
- Vehicle location and voice/data communication capability have been added to provide the platform for a new AVLC system. This is based on a centralized Control Centre that manages services on a real-time basis.
- The AVLC supports real-time passenger information on internet and at bus-stops. The RTPI (Real Time Passenger Information) server and at-stop displays are managed by the city.
- The ITS has been based on the business and operational requirements.
- The AVLC is in its first full year of operation, and has not yielded quantified resource or operational benefits.

Scope of the Case Study

[3] Source:The World Bank - Toolkit on Intelligent Transport systems for Urban Transport

This case study deals with the ITS implemented at Dublin Bus, the public bus operator in the metropolitan area of Dublin.

It does not cover the ITS implemented at the rail or tram operators, or any ITS at the small number of other operators of urban bus services, except where this is directly relevant to the ITS implemented at Dublin Bus. Likewise, it does not cover ITS implemented by the city for traffic management or other transportation services, again except where it is relevant to or interfaces with the Dublin Bus ITS (in particular the real-time information)

Due to the central role of the Electronic Ticket Machines in the ITS implemented at Dublin Bus, the technology is covered in this Case Study, insofar as it forms part of the ITS platform and the development/migration path.

Context

Dublin has a population of 1.2 million people; the broader metropolitan area population is about 1.6 million people.

Public transport in Dublin consists of the following:

- Urban bus services
- Tram/light rail ("Luas", 2 lines, implemented in 2005)
- Urban commuter rail (DART, 1 line, renovated in 1984)
- Suburban commuter rail (multiple services sharing the mainline tracks)
- Outer suburban/hinterland bus services

Urban bus is the primary means of public transport, providing citywide coverage and carrying more passengers than the other public transport modes combined.

Overall, public transport mode share is low, although this varies greatly across the metropolitan area. Public transport has a relatively high modal share for trips entering the central area during the peak hours (>50% on some corridors). This quickly tapers off with distance from the centre. Private car is the dominant mode outside the Centre, and for suburban and peripheral travel. Cycling and walking have low mode shares, despite being favored in policy terms. Taxis are deregulated, plentiful, and relatively expensive, and have a low share of the travel market.

Operator Structure

Dublin Bus is the dominant operator in Dublin. It has had a de facto monopoly of urban bus services in Dublin for over 60 years, reflecting national policy. Dublin Bus is a wholly-owned subsidiary company of the CIE Group, which in turn is a public entity owned by the Minister of Transport.

Over the past decade, some licenses have been granted for non-subsidized services from outer suburban areas to the city and for specialist services such as to the Airport. However, these are negligible in terms of market share of the urban bus business.

Dublin Bus

Dublin Bus operates approximately 200,000 km. of service per day using a fleet of c. 980 double-deck buses. Dublin Bus did previously operate articulated buses, but these have been phased out for operational reasons. There had also been a major move towards single-deck buses during the 1990's, but these have also been gradually phased out and the fleet has reverted to double-deck buses.

Dublin Bus operates from seven depots, most of which are in the city and inner suburbs, with the fleet currently allocated as follows:

- **Clontarf** 85 buses
- **Conyngham Road** 98 buses
- **Summerhill** 103 buses
- **Ringsend** 117 buses
- **Phibsboro** 180 Buses
- **Harristown** 183 buses
- **Donnybrook** 214 buses
- **Total** 980 buses

Key metrics for Dublin Bus in 2009 were:

- **Passengers** 128 million
- **Revenue** €196 million
- **Costs** €292 million
- **PSO payments** €83 million
- **Deficit** €13 million

Dublin Bus have reduced their fleet from over 1100 buses due to two perhaps not unrelated factors, and the downsizing is not yet complete:

- Passenger numbers dropped significantly since 2008 due to the economic crisis, leading to less revenue, bigger deficits. The fleet was reduced in line with the changed demand.
- The Network Direct project restructures the network, simplifying the routes, channeling the services towards the main roads and reducing meandering variants through residential estates.

Dublin Bus currently has a total of 3,685 staff of which operating staff includes:

- 2,545 Drivers
- 139 Supervisors
- 15 Chief Supervisors

Performance targets that are relevant to the ITS applications include:

- % of planned trips and kilometers operated
- % of trips departing not more than 5 minutes late
- % of destination scrolls set correctly
- participation in the Integrated Ticketing System

Motivations to implement ITS

The principal motivations to implement ITS at Dublin Bus have been:

- Develop (and subsequently renew), a secure and effective revenue collection system – this has formed the backbone of the ITS
- Develop enhanced operations management capacity to provide reliable services and deal with disruptions
- Provide communications for staff security
- Provide improved passenger information
- Obtain data for planning, resource optimization and performance monitoring

Previous experience with ITS

Dublin Bus was one of the pioneer implementers of AVLC systems, referred to as AVM (Automatic Vehicle Monitoring). In the 1970's, after some years of radio-based route management, it decided to implement automatic vehicle location. The technical system was deployed in a pilot depot in 1977, and following intensive testing and some modifications, was rolled out on a depot by depot basis with completion in 1981.

The technology was based on in-vehicle processing units linked to voice/data radios and to a driver console. Location was based on odometer readings that incremented an initial value set by the driver. All 1,000 vehicles were polled over a 45 second cycle, returning a message that included location and status indicators. Data was processed through a centralized computer system, which hosted both central and depot-based applications. The central system stored the reference route and schedule data, and combined this with the real-time location and status data to provide the information required for the AVM functionality.

Dispatching was organized at depot level. Each of the seven depots had two workstations equipped with display screens and voice radios. The screens allowed the dispatchers to see route schematics that displayed the actual and scheduled positions of all vehicles associated with the route. Alarm messages, requests to speak and other status information were also displayed. As in the current system, drivers could not initiate voice calls, but instead pressed a 'Request to Speak' button and the dispatcher would call the driver when appropriate. An Alarm button could override this, in case of emergency.

Operations management procedures advanced rapidly when Dublin Bus was able to switch from radio control to AVM. Initially, the dispatchers were able to focus their attention on vehicles requiring attention. Over time, a corpus of experience was developed, including the ability to 'read' the route and to bring a greater degree of anticipation to problem identification and resolution, rather than the

previous reactive approach. An anticipatory approach allowed problems to be resolved and dissipated before they became disruptive and required stronger intervention. A range of interventions and response measures was developed, both to maintain the scheduled service and to recover the structure of the service in case of disruption.

Separately, in 1985-7, a pilot project on traffic signal priority was implemented on the 100 buses from Ringsend depot, and a cluster of 9 junctions in south-west suburbs of Dublin. This was based on infrared transponders installed on the buses, and roadside detectors linked to the traffic signal controllers. The system was then linked to the AVM system to identify the schedule status of the buses, such that on-time and late buses received priority, but buses ahead of schedule did not. This system was successful, but was not extended due to funding issues.

While the corporate knowledge of AVM was not lost, in all other respects the AVM terminated completely. It did not provide a logical, network or functional platform for the ITS system described in the next section. Although they overlapped, the Electronic Ticket Machine was designed and implemented independent of the legacy AVM. This was a reasonable approach, as a new AVM system would have been fundamentally different from the original (availability of Windows, improved screen displays, emergence of GPS, move away from solid-state technology).

Applications for which ITS is currently used at Dublin Bus

ITS at Dublin Bus has been deployed and enhanced over an extended period, in most cases building on the strengths of previous implementations. The deployment path of ITS systems at Dublin Bus is listed as follows:

1989 Electronic Ticket Machines

1990-1 Magnetic Card Readers

1995 Autofare

1999 Electronic Destination Scroll

2001 Trunked Radio System

2005 Replacement Electronic Ticket Machines

2008 Smart Card System and Readers

2009 Radio system upgrade

2010 AVL and Control Centre

2011 Real-Time Passenger Information (RTPI)

2011 Integrated ticketing

Operations Management

The primary Operations Management is now carried out through the ITS-supported Control Centre. A number of functions have been centralized at the Control Centre at the ITS Centre in Broadstone (adjacent to Dublin Bus' Phibsboro Depot):

- AVLC Control Centre
- Revenue Protection Unit
- Customer Information / Call Centre

Prior to the AVLC project, dispatching had been carried out in the individual depots. This has been the practice in the radio-controlled dispatching in the early-1970's, in the AVM period of c.1977-1994, and in the post-AVM period.

Since the original AVM was closed in 1994, the dispatchers no longer had real-time location information. When the new radio system was implemented, the dispatchers had radio contact, but had to ask the drivers where they were and rely on what they were being told. As a result, dispatching was a reactive activity with a lot of guesswork.

Prior to the new AVLC, there was a total of 32 Depot Controllers, with each of the 8 depots controlling its own routes. In addition, there are 20 Street Supervisors. These are mostly assigned to morning and evening peaks. They have hand portable radios (and lots of back-up batteries) and have a linkage with the dispatchers.

System Integration

There is not a formal System Architecture for Dublin Bus' ITS and IT systems.

Dublin Bus is not dependent on the continuity of knowledge of a single person. There is a team in place consisting of three full-time persons and supplemented by two other persons during the deployment phase. All specifications and interfaces are fully documented, and there is a change control process in place. Much of the detailed documentation is done by, maintained by, and retained by the suppliers, with whom Dublin Bus have good working relationships.

Management and Oversight of the ITS Systems

All ITS used at Dublin Bus been specified, procured, installed and operated by Dublin Bus.

The National Transport Authority has responsibility for the RTPI and the Integrated Ticketing System. Responsibility for RTPI in the Dublin area, including implementation, has been assigned to Dublin City Council. Responsibility for all aspects of the Integrated Ticketing System has been assigned to the Rail Procurement Agency.

Data generation and acquisition for RTPI are performed by Dublin Bus, and the data is transferred to the DCC RTPI server. Dublin Bus has specified, procured, installed and operated their own Fare Collection systems, but is required to be compliant with the RPA's Integrated Ticketing System.

All operations management and control is carried out internally by Dublin Bus. There is no hierarchical structure involving either the transport authority or other operators.

Implementation and Operational Challenges

Training and Mentoring

It was necessary to develop the PC skills of those who would be the dispatchers of the AVLC. These skills were lacking, and City of Dublin VEC was brought in to assist with both basic PC/keyboard skills, and with processes such as CCTV requests, reporting, managing files and folders, etc.

A mentoring process was also put in place. Dispatchers were trained in making safety announcements. Engineering staff were also given training. Each depot sent representatives to the Control Centre to understand what happens there, why properly functioning equipment is important, and to interrelate with the Control Centre staff.

About 10 drivers per day are brought to the Control Centre as part of their ongoing CPC training courses. This builds their understanding of the Control Centre – which they would never see otherwise, since it is not attached to any depot.

Support Activities to getting started

For all of the routes, safe locations were identified for short layovers – i.e. where the bus can be asked to hold for a few minutes if it is moving ahead of time or the intervals need to be regulated. These have been identified, listed, and form part of the toolbox for the Dispatchers.

One of the more senior dispatchers has been assigned full time to the Dublin City Traffic Control Centre. He deals both with daily issues that arise, and the planning for how to manage or divert the bus services for specific events.

Transition

While the AVLC equipment was being rolled out throughout the fleet, the AVLC operation commenced on a vanguard route (route 123). One of the dispatchers (a former driver himself) was given the lead role from the dispatcher side, which included establishing the dispatcher practices.

For the first two months, he would call the drivers to tell them their actual departure time from the terminus (especially if they left early) based on the real-time information coming to him from the AVLC. At this stage, he was not trying to control their operations, but simply reinforce that they were visible to him. Although the drivers said they had not yet received instruction from their Unions to co-operate, the point was effectively made and drivers began to depart at the correct times.

This helped to establish some ground rules, without having to go through a process of confrontation and dispute. Most drivers were happy to have it work properly, since drivers who departed early were causing problems for everyone.

Deployment Challenge

The ITS – and the AVLC in particular – impacts on the standard operating procedures. As a result, it usually needs to be done fleet-wide. Dublin Bus consider that cannot be done piecemeal where some routes are on the system and others not.

This gives a logistical challenge where installation must be done on 1,000 buses and 2,500 drivers need training and to consistently use new or adapted procedures.

This required a lot of planning, resource and management commitment. Nonetheless, it did not produce any significant obstacles or challenge beyond the resource and time involved.

Reports and analysis

The database used by Dublin Bus is Mobile Statistics. The challenge is how to interrogate it so that they get meaningful reports.

- They can set up daily, weekly, bi-weekly, monthly reports, etc.
- They are trying to get to a point where managers can get the 'heads-up' reports they need to draw their attention to where there may be problems, where they need to look more closely.
- They should then be able to go into more detail – e.g. track a route for a period of time, track an individual trip/bus, examine a specific route section

A large part of what has been done in the initial months (note that the system is still in the first year of live operation at time of writing) has been cleaning of data, report structures, anomalies, etc.

Comparison of the AVLC data and what is actually happening on the street is a necessary stage in the first year, since it cannot be presumed that the AVLC is 100% accurate. They have found very good correlation, albeit with some anomalies. The first pass of these anomalies have found some drivers not initiating things correctly, perhaps also some equipment not calibrated correctly, these will be normalized quite quickly. There are still some items that cannot be readily explained, they are investigating, teasing it out, figure out what this means and if resolutions can be found, or it there will always be some quirks within the system.

ITS Maintenance and Support

Dublin Bus has established supply, maintenance and support agreements with the suppliers of the ITS equipment and systems. This includes the regular maintenance and bi-annual site inspections.

There are currently no 3rd party maintenance contractors. All maintenance is done either by the suppliers or by their appointed agents (who must be approved by Dublin Bus).

Dublin Bus recommends this approach and has found it invaluable, although it does come at a price. At this stage, Dublin Bus has worked with the radio and fare collection system supplier for many years. The systems always need adjustment, enhancements and upgrades, and a good working relationship allows this to be done without fuss or having to launch new procurements – it can be done as a request or if necessary as a variation order. Probably more importantly, their suppliers understand the systems and their history.

Dublin Bus considers that it becomes particularly important where there is integration between systems, and either new functionality must be added or problems identified and resolved. As they need to work with two or more suppliers, it is essential that all parties have good working relationships with each other, and are interested to find a good solution.

Another advantage is that their radio supplier (Tait) and AVLC supplier (INIT) co-operate on other projects. On one hand, it means that they are familiar with each other's systems. On the other, it means that they are developing extended functionality, enhancements and bug-fixes for other Clients. Some of these enhancements appear in the upgrades that Dublin Bus gets as a matter of course, in other cases it allows the suppliers to respond more quickly to requests from Dublin Bus.

Capital Costs of the ITS

Detailed costs are not available (known to Dublin Bus, but not in the public domain). The total costs for the ITS – radio, AVLC, back-office systems – is in the €8-9 million range for 1,000 buses.

Dublin Bus would not have been in a position to make these investments without the financial support from Department of Transport, Transport 21 and the NTA.

Benefits arising from the ITS systems at PRTC

The achieved/perceived benefits of the ITS investments have been:

- Reliability of service
- Reduction/virtual elimination of buses departing early from termini
- Data on service performance
- More precise/appropriate scheduling (sectional journey times, variances)
- Use of speed/delay data to identify delay points and supporting case for traffic management improvements or bus priority
- Data to support (RTPI)

7.2 Zurich, Switzerland[4]

Overview

- Public transport in Zurich is provided by VBZ, a multi-modal operator of trams, trolleybuses and buses. Trams form the backbone of the system.
- The basic concept is that the City provides an excellent operating environment, and VBZ should operate on-time services within that frame
- The ITS is integral to the VBZ operation, and to the organization, business processes, operating procedures, data, and management. The approach has matured over the four decades as they gain better understanding of what they can do, embed it in the organization, and evolve the technology.
- VBZ has evolved from using ITS to just know where their vehicles are, to precision operation with on-time running and transfer assurance
- Passenger information is extremely well-developed, prior to the trip, at stops and in the vehicles. It provides a seamless and ubiquitous guidance.

Scope of the Case Study

[4] Source: The World Bank – Toolkit on Intelligent Transport Systems for Urban Transport

This case study deals with the ITS implemented at VBZ Zurich, the multi-modal surface public transport operator for the metropolitan area of Zurich and its immediate hinterland.

It does not cover the ITS implemented at the regional rail operators. It does not cover ITS implemented by the city for traffic management or other transportation services, except where it is relevant to or interfaces with the ITS of VBZ.

For the purposes of this Case Study, 'bus' and trolleybus' are collectively referred to as 'bus', except where the difference is relevant. For the purpose of the ITS in Zurich, there is no significant difference between tram and (trolley) bus, with the systems and operations management common to all.

Context

The Canton of Zurich has an area of approximately 1,700 sq. km and a population of 1.37 million. It consists of 171 communities.

Public transport in Zurich consists of the following:

- Long-distance and regional rail
- Suburban rail (S-Bahn)
- Trams
- Trolleybuses
- Urban bus services
- Outer suburban/hinterland bus services
- Demand Responsive Transport

The S-Bahn and regional rail are the main means of passenger transport from the hinterland to the city of Zurich. S-Bahn operates about 950 trains per day on 26 lines with 176 stops in Zurich region, and carries about 380,000 passengers per day. Tram is the 'backbone' of the Zurich urban transport system, with bus and trolleybus playing complementary role. Nonetheless, the S-Bahn is preferred even for trips within Zurich where it is suitable as it is the fastest mode and well integrated with the other modes.

Operator Structure

VBZ is an integrated multi-modal transport provider, owned by the City of Zurich. VBZ direct operates tram, trolleybus, bus and funicular services in Zurich and its hinterland. Rail services in the area are provided by S-Bahn (SBB). Some bus services within the coverage area are operated by other operators, under agreement with VBZ.

The key statistics for the VBZ operation are:

	Tram	Trolley bus	Bus (urban and suburban)	Total
	13	6	60	79

Vehicles	313	80	261	654
Network length (km)	113	54	628	795
Passengers (Million)	202	55	61	318
Passenger-km (Millions)	369	119	143	631

The network has a total of 451 stops in the urban area and a further 330 in the region, total 781 of which 553 have waiting rooms and/or shelters.

VBZ has a total of 2,371 staff of which 1,366 are in direct operations.

Total income for VBZ in 2008 was CHF 467 Million (c. USD 520 million). Cost recovery is approximately 64% across all modes.

VBZ has a total of 5 depots. Two of these are solely tram, one is for trolleybuses and one is for buses only, and one is mixed.

Motivations to implement ITS

VBZ has utilized ITS since 1971. At this stage, ITS is a completely integral part of the VBZ business processes and means of operation.

- The motivations for utilizing the ITS include the following:
- To provide a reliable service that operates according to the schedule at departure and along the route
- To provide priority for public transport at traffic signals, and thus minimize delays at junctions and variations in travel time
- To ensure that planned transfers can be achieved ('connection protection')
- To have the capacity to deal with events, disruptions and emergencies
- To provide real-time and other information to passengers before the trip, at stops and in vehicles
- To achieve integrated and seamless travel across modes
- To gather, analyze and utilize extensive data
- To optimize the resource utilization and maximize efficiency

The requirements have evolved over time as VBZ have become familiar with using ITS, and with the data it provides, and as they have built their organization around it.

Applications for which ITS is used at VBZ Zurich

The scope, functionality and devices for ITS have evolved over about 40 years since ITS was first utilized at VBZ.

ITS is used for the following applications at VBZ Zurich:

- Automatic Vehicle Location
- Operations Management, including Incident Management
- Traffic Signal Priority (limited ITS content)
- Fare collection
- Real-time passenger information pre-trip, at stations and in vehicles
- Automatic Passenger Counting
- Timetabling
- Vehicle and driver scheduling

ITS supports and/or exchanges data with the following:

- Manage driver roster
- Maintenance planning
- Travel and traffic information

ITS Equipment and Devices

In-vehicle ITS-related equipment consists of:

- On-board computer
- GPS
- Radio (voice, data)
- Wireless LAN (in-depot data transfer)
- Driver console
- Display screens for RTPI
- Voice announcer (interior)
- Voice announcer (external, some vehicles only)
- Transponder to interface with roadside detector (trams only, both for traffic signal preemption and for point switching)

There is no fare collection equipment on board the vehicles used in the City of Zurich. There are ticket issuing machines and card validators on some buses that operate suburban services in the hinterland.

Station/stop equipment ITS-related equipment consists of:

- Displays for RTPI
- Self-service ticket vending machines
- Depot ITS-related equipment consists of:
- Wireless LAN/Ethernet for data exchange with vehicles

AVL and Operations Management

The ITS for AVL consists of four main elements:

- In-vehicle integrated computer
- In-vehicle driver console

- Control centre workstations
- Control centre software

The in-vehicle integrated computer is an IBIS Plus unit. The unit has evolved over time as technologies change, but is essentially the same concept of an on-board unit linked to a driver's console, various in-vehicle devices and a radio.

It comprises a 19" rack with the following integrated elements:

- Computer/core processing unit
- GPS/Location Unit
- Wireless LAN
- GSM Unit
- Reference data store
- Transaction store

The unit is the central hub of all the on-board ITS devices, except for ticket issue and ticket validator units on buses where these are installed.

Driver's Console

The driver's console is now an extremely versatile unit. It consists of a high-definition, multi-function, and touch-screen display. The console is a display unit, providing a user interface to the on-board applications, all processing and data storage functionality is in the on-board computer.

When the driver turns on the engine at the start of the shift, the console is activated. The on-bus computer resumes from sleep mode, and the in-vehicle display units are switched on. The driver enters his/her driver number and the route/duty data. The on-bus computer retrieves the trip information associated with that duty and displays the next scheduled trip. The driver confirms that this is the correct trip, or can manually select another trip if necessary. After that, all route and trip information updates automatically.

The normal display mode on the driver's console shows the following:

- Top line: Route/duty; time, destination, position relative to schedule (+/-, in color box)
- Right side bar: Tools including Request to Speak, Alarm, message request, other menu options
- Main body of screen: Route shown vertically, with current stop at the top, next three stops with their scheduled arrival time, and indicator of whether there is connection data available
- Bottom of screen: Destination/terminus and scheduled arrival time

The driver's console can display other information on the screen, including:

- Real-time information on connections at current and subsequent stops. This allows the driver to check and decide whether to wait for other connections, and also to answer any queries from passengers.
- Messages from the Dispatcher/Control Centre
- Message menu, from which one can be selected for communication to the Control Centre

- Visual of bus occupancy options (empty through to full with passengers left behind) which can either be initiated by the driver or prompted by the Dispatcher

The driver's console can also be the interface for fare collection (this is only used for the bus services outside the city where fares are collected on board). Any fare collection equipment is logically independent of the IBISPlus on-board computer. There is a network linkage, allowing the driver's console to service as the interface or display for the fare collection system.

Voice communication is restricted, and is controlled by the dispatcher. The driver has three options to request voice communication:

- Press a 'Request to Speak' icon on the driver's console. This is shown on the dispatcher's screen, the dispatcher will decide whether and when to initiate a voice call with the driver
- Press an Alarm icon on the driver's console. This is shown on the dispatcher's screen with a flashing sign and an audible alarm. The dispatcher will initiate the voice call with the driver.
- Press a hidden emergency button. This will show with a special flashing sign on the dispatcher's screen, and with a loud alarm sound. Voice communication is automatically opened up, allowing the dispatcher to hear what is going on in the vehicle.

Communication

The primary communication for operations management is performed by private analog radio. Radio communication is full duplex, which is rare in the public transport industry. VBZ has an extensive network of base stations, both in the city and outside. This allows all radio communication to be performed on the analog radio system in the city, and along the main service areas outside the city. There are some rural areas where it has not been cost effective to establish their own base stations, so they either lease space on other utilities' masts, or they supplement the analog radio with GSM.

Close range communication is performed by wireless LAN, which is integrated into the IBISPlus on-board computer. Wireless LAN coverage is available throughout the depots, so vehicles can exchange data wherever they are (e.g. parked, at maintenance, at washing/fueling). Wireless LAN has also been placed at a few key locations. Data exchange takes place on an 'opportunistic basis', including for some vehicles if they are passing by the depot. The system keeps track of which data packets have been successfully transferred, and if the data transfer is not complete, it resumes at the next opportunity.

Data transfer includes:

- Upload of reference data (routes, stops, schedule, …)
- Download of transaction data, statistics, logs, etc.
- Software upload and configuration changes

Data can also be transferred through the radio system if necessary, but this is generally avoided as it uses up the more scarce capacity.

For the trams, the transponders communicate route information to enable automated point switching.

Real-time Passenger Information

Passenger information consists of multiple strands:

- How to use the transport system
- Journey planners
- Real-time passenger information
- Incident information and alerts

Real-time passenger information is based on the AVL system. RTPI is provided through four main channels:

- Internet and mobile channels, delivered to personal devices
- At-stop displays
- In-vehicle displays
- Displays at 3rd Party locations

There is increasing interest in internet and mobile channels of providing RTPI, as information provided before the customer arrives to the stop allows the customer to either choose a better trip alternative, or to manage their time better.

RTPI at stops is provided on pole-mounted displays. The units are based on LED displays, and normally provide four lines of information, indicating the next four vehicles to arrive at the stop.

The information shows:

- line number
- destination
- minutes to arrival
- wheelchair symbol, if the vehicle is accessible

The data is transmitted through wireless to the individual stops from the AVM system.

RTPI in the vehicles is provided on high-definition display screens. The unit has a light sensor, and varies the luminance level depending on the ambient light (i.e. turns it down at night, increase in bright sunlight). This reduces power consumption and generated heat where possible.

Relevant baseline information (line, stops, schedule, and transfer information) is stored in the on-bus computer and is updated periodically as required. The real-time information is provided by the AVM system.

There are three main display modes for the on-bus RTPI

- Normal mode, showing information for the next stops
- Connection information at transfer points
- Messages and alerts from the VBZ Control Centre

This information is packaged from the data stored in the on-board computer, and supplemented by the real-time status of the individual routes (the two right-hand columns).

When required, information and alerts can be displayed on the in-vehicle screen.

The messages are generated at the VBZ Control Centre. The Dispatcher can choose from:

- Preset messages
- Message templates into which context-specific data can be added (e.g. route number, time, date)
- Free-form text generated by the Dispatcher.

The message may be accompanied by a prerecorded voice announcement. The Dispatcher also has the option to make a voice announcement.

Traffic Signal Priority

A very high level of priority is given to public transport at traffic signals in Zurich. This is managed through the Traffic Control Centre of the City of Zurich. There is no direct interaction with the foreground or back-office ITS of VBZ.

The basic principle is that the Traffic Control system manages the general traffic to minimize congestion, and then gives as much priority as possible to public transport according to the specified rules (see below). It does so regardless of whether the vehicle is on-time, early or late. From the Traffic Control Centre perspective, it is the task of the transport operator to operate services to schedule within this favorable operating environment.

The Traffic Control Centre has comprehensive traffic status information - at network, link and junction level – various analysis routines, and has CCTV coverage of key points.

Traffic signal priority is triggered by detection of public transport vehicles. This is based on the traffic management devices, and it does not receive any location information from VBZ's AVL system.

Zurich has about 400 sets of traffic signals, and about 4,000 traffic detectors, most of which are induction loops. The induction loop detects the vehicle presence, and is able to identify if it is a public transport vehicle. Detectors are located in the lanes used by tram and by bus, assisting the vehicle type and direction logic.

For each junction and approach, a set of priority rules is established. This needs to consider both the priority action to be taken when there is a one public transport vehicle and the allocation of priority if there is more than one public transport vehicle detected. The underlying concept for these rules include normally giving tram priority over bus, and peak direction traffic gets higher priority. The junction configuration is also taken into account. If there is no applicable rule, then it is 'first come, first served'.

The normal means of giving priority is to truncate the current phase (if required) and to give an early green. This is normally done by adjusting the phase time without altering the phase sequence, with some tolerances about when the current green phase is completed. There are some background rules, including that the total cycle time cannot exceed 72 seconds, and maximum pedestrian waiting time is 30 seconds.

In some cases, especially for the tram routes in dedicated lane, it is programmed to give zero-wait, meaning that the traffic signal will always be green when the vehicle reaches it. The vehicle can approach the junction without reducing speed, confident that the light will be green by the time it gets there. This has implications for driver training and safety, since there are not the same level of priority at all junctions.

Detector reliability is very high, with just 1 to 5 detectors requiring to be dealt with each day (out of a total of 4,000). The central system can detect faults, and will trigger an alarm if no signal has been received within a specified period of time.

The Traffic Control Centre will co-ordinate with VBZ's Control Centre for events, road closures, disruptions, etc. They do not interact in relation to the normal public transport operations. For example, the Traffic Control Centre workstations to not have access to the VBZ service information or route displays.

Outside the City of Zurich, where the traffic signals are not part of an integrated urban traffic control system, traffic signal priority is activated by the VBZ AVL system sending location/arrival data directly to the individual traffic signals. The local signal processor deals with the requests and grants the priority as appropriate.

Scheduling

VBZ uses the DIVA scheduling package. This is used for the full sequence from timetable generation, vehicle scheduling and driver scheduling. The initial timetable is developed directly within DIVA (i.e. it is not done manually and then entered). All of the detailed timetable and scheduling development is done by the software. The exception is the transitions (e.g. from 7.5 minute to 10 minute headway at the end of the morning peak) where some smoothing may be done manually.

The timetable is developed entirely according to the customer requirements. While there are working hour, shift and layover constraints, these are a matter for the driver scheduling and roster functions, and the timetable is never manipulated to suit such driver-related constraints.

Fare Collection

Normally there is no fare collection equipment within the VBZ vehicles. All tickets are purchased and validated before boarding. There are neither ticket issuing machines nor validators.

There are self-service vending machines on the platform at which customers can purchase tickets. These offer tickets throughout the Canton of Zurich, users select how many/which zones they wish, how many trips, any applicable discount, etc. The machines accept cards and cash.

All tickets are currently paper. Journey and day-related tickets must be validated prior to travel. A mechanical punch removes part of the ticket and makes a time, date and location stamp. No further validation is required, and the ticket can be used on all VBZ modes throughout its validity.

There is discussion about migrating to smart cards, but no firm commitment has yet been made.

System Integration

The ITS systems are deeply integrated. This has evolved over the four decades of ITS at VBZ, rather than being implemented from a master template.

The on-bus computer unit provides the primary integration of all on-board ITS-related devices (except fare collection, where they are used). It hosts the on-board network and holds the reference data required by the various devices/systems.

Within VBZ, the ITS is fully integrated across modes. For ITS purposes, trams, trolleybuses and buses are treated as equal, being the vehicles assigned to public transport lines. The ITS equipment and functions are the same, although some aspects of the configuration and the number of devices on-board may vary. Key interfaces between the AVL and other systems include:

- Scheduling (DIVA)
- S-Bahn (SBB) to exchange real-time information and transfer information
- RTPI for smart phones
- Integrated ticketing system
- SAP, for maintenance scheduling (including unplanned work)
- 3rd party / external systems

Benefits arising from the ITS systems at VBZ

VBZ has used ITS for operations management for almost forty years, and has made real-time information available to passengers for almost twenty years. It is an integral part of their business and operational processes, and it is inconceivable that they would operate without such systems.

In the course of four decades, VBZ has moved far beyond trying to know where their trams and buses are, whether they leave on time, or looking for data about the day's performance – all these things have long been treated as baseline. VBZ works on the principle of operating their service according to the schedule, optimizing the resources to do this, and guiding the customer through the trip.

7.3 Izmir, Turkey[5]

Overview

- ESHOT is the municipal-owned operator of the bus network in Izmir and its surrounding service area. It operates a fleet of 1,560 buses, including 410 from its associate Izulas.
- The bus network forms part of an integrated transport system including Metro, Rail, Ferry, and local paratransit. Integration has been developed since 2000, and suburban rail was included in 2010.
- The company has implemented extensive ITS since 1999, when smart-card ticketing was first introduced. The ticket validators have provided the backbone of the on-bus intelligent network.
- Vehicle location and voice/data communication capability have been added to provide the platform for a new AVM system. This is based on a centralized Control Centre that manages services on a real-time basis.
- The AVL supports real-time passenger information on buses and at bus-stops. The communications capability is also utilized for surveillance.
- AVL data is also utilized for fuel issue monitoring and bus maintenance scheduling.

[5] Source: The World Bank – Toolkit on Intelligent Transport Systems for Urban Transport

Scope of the Case Study

This case study deals with the ITS implemented at ESHOT, the municipal bus operator in the metropolitan area of Izmir. It does not cover the ITS implemented at the metro, rail or ferry operators, except where this is directly relevant to the ITS implemented at ESHOT.

Likewise, it does not cover ITS implemented by the city for traffic management or other transportation services, again except where it is relevant to or interfaces with the ESHOT ITS.

Due to the central role of the e-ticket on-bus validators in the ITS implemented at ESHOT, the technology is covered in this Case Study insofar as it forms part of the ITS platform and the development / migration path.

Context

Izmir is Turkey's third largest city (after Istanbul and Ankara) and has developed over the past 3,500 years around the Gulf of Izmir off the Aegean Sea. It now comprises 11 metropolitan districts brought together under unitary authority, and a further 10 districts are wholly or partially included in the new municipal arrangements.

Izmir Metropolitan Municipality had a population of some 3.35 million in 2010, with the peri-urban area adding a further 0.6 million. Population increase in the municipality over the past decade has been some 50%, primarily because of recent boundary changes but also because of inward migration and natural growth.

Public transport in Izmir consists of the following:

- Urban bus services, operated by ESHOT and Izulas, with 1,560 vehicles
- Urban ferry services, operated by Izdeniz; 24 ferries, using 8 quays
- Metro rail, operated by Izmir Metrosu; 1 line, launched in 2000
- Suburban commuter rail, operated by IzBan; 2 lines, launched in 2010
- Peri-urban/hinterland bus services, operated by ESHOT
- Hinterland paratransit services, operated by dolmus

There has been considerable renovation and expansion of the ESHOT bus fleet in recent years, introducing both low-floor and articulated buses and adding air-conditioning to nearly half of the vehicles. No plans for bus-based rapid transit (BRT) were advised, though.

The primary means of private travel demand management is parking control, with strongest enforcement in the central areas and in suburban hubs. This is primarily based on dissuasive pricing mechanisms, and to a lesser extent on quantity control. However observation suggests that this is not wholly effective.

ESHOT Structure

ESHOT operates as five divisions in the urban area, with two minor sub-divisions in the hinterland of the city. The numbers of routes operated by each division, and the vehicles allocated to each are as follow:

Division	Routes	Vehicles	ESHOT	Izulus

Buca	50	328	308	20
Konak	74	306	266	40
Bornova	60	378	235	143
Karsiyaka	80	375	305	70
Teleferik	40	287	272	15
Torbali	13	24	24	0
Urla	3	8	8	0
Total	**320**	**1706**	**1418**	**288**

Note: Vehicles include the ancillary fleet; service buses total 1,561.

The large majority of the fleet is standard-length single-deck buses, but 200 articulated buses were introduced from 2008 and 42 new mini-buses added to the Izulas fleet in the same year. 744 of the buses are now air-conditioned (including retro-fits), and 444 have low floors and step-less entry equipped for wheel-chair access.

The major investment program from 2007 onwards has increased the fleet from 1,120 to 1,560 buses, and reduced its average age to 8.91 years. 90% technical availability is achieved, now providing 1,400 buses for daily operation.

ESHOT operates from twelve depots, of varying sizes, most of which are located in the city and inner suburbs; five of these depots have full workshop facilities.

Key daily metrics for ESHOT operational performance are:

- **Fleet operated** 1,400
- **Departures** 11,000
- **Kilometers** 320,000
- **Passengers** 1.3 million
- **Kilometers/bus** 230
- **Passengers/bus** 930

ESHOT had 3,760 staff in 2009, of which 2,768 were drivers. This is a ratio of 2.7 staff per operating bus.

Motivations to implement ITS

The principal motivations to implement ITS at ESHOT have been to:

- Develop a secure and effective revenue collection system – this has formed the backbone of the subsequent ITS applications
- Enable modal and service integration through minimizing personal costs of interchange

- Develop enhanced operations management capacity to provide reliable services and deal with disruptions
- Provide improved passenger information in real-time
- Provide surveillance for passenger and personnel security
- Obtain data for planning, resource optimization and performance monitoring

Overview of ITS deployment at ESHOT

ITS at ESHOT has been deployed and enhanced over an extended period, in most cases building on the strengths or capabilities of previous implementations.

The deployment path of ITS systems at ESHOT is summarized as follows:

1999	Introduction of smart-card e-ticketing on pilot basis
2004	Completion of e-ticketing roll-out for all travel on ESHOT
2006	Automatic vehicle location implemented
2007	Introduction of transferable tickets across modes on pilot basis
2008	Completion of transferable tickets across all modes
2009	Fuel issue and stock control system
2009	Operations Control Centre
2010	Real-time passenger information at bus-stops and on buses
2010	Passenger surveillance systems

The smart-card e-ticketing system was the first ITS system at ESHOT, and was originally intended as a stand-alone application. However the on-vehicle validator that was developed by the local equipment supplier had embedded capabilities for automatic vehicle location, as this had been required for another city introducing e-ticketing at the same time.

The validator was also equipped with a communications capability, initially to receive 'black-lists' of invalid smart-cards, and this could be adapted to AVL, RTPI, and surveillance applications. The e-ticketing validator has therefore provided the data center and intelligent hub for all subsequent ITS applications at ESHOT.

Automated Fare Collection

This application is covered in greater detail in the case-study on fare collection in Izmir for the parallel World Bank toolkit currently being developed for that topic. The following is a summary of the key implications of the application for the subsequent deployment of other ITS systems at ESHOT.

Electronic ticketing was introduced to Izmir in March 1999, with the Akilli Kart. This employed Korean technology for the contactless smart-card and validator, and a Motorola communications system. At this stage, this was a standalone application designed to improve revenue integrity and protect against fraud.

However the system integrator contracted by ESHOT for this program found that working with foreign suppliers was problematic, and it was agreed that this should be replaced by locally designed

and manufactured hardware. This was applicable not only to Izmir, but to 3 other cities in Turkey with which the system integrator was working at that time.

The benefit of this local development was that the equipment was designed for a range of applications identified by the different cities, and was compatible with all industry-standard smart-cards. The supplier claims a world first for the integration of Automated Fare Collection and Vehicle Tracking Systems in a single unit as a result. Communications were also migrated onto GPRS, removing dependency on a dedicated wireless network.

In the initial application conventional paper tickets retained validity, and a special card allocated to each driver was used to enter the travel details for passengers who did not hold a smart-card – now known as KentKart (CityCard in Turkish). This card has been retained and adapted for other applications, even though it is no longer needed for the fare collection system after all driver involvement in that process ceased in September 2009.

In February 2007 a pilot application for transferable tickets between modes was launched initially involving ferries, metro, and 100 buses on 52 routes that provided feeder services. This offered a 50% discount on a second boarding made within 60 minutes of the first, and hence required the timed transactions to be written to and read from the smart-card.

This transfer capability was extended to 90 minute validity in January 2008, and the discount for any subsequent boarding increased to 100% in August 2008. In effect, this has introduced a flat-fare structure for passenger transport across Greater Izmir for all holders of smart-cards.

Because of this fare structure, ESHOT buses are only fitted with ticket validators at the entrance door and there is no need to revalidate at exit. Although not needed for the fares validation, the transaction records the location of the bus at that time using the automatic vehicle location capability of the validator.

As a result, travel path data availability gathered from ticketing transactions is only partial in that any points of interchange are captured but not the point of final alighting. Nevertheless this can be determined for regular commuting journeys from the point of first boarding for the reverse trip.

ESHOT has used the travel path data generated from the ticketing transactions, and the freedom provided by the elimination of interchange-costs from the new fare structure, to recast its route network. This has now been directed towards planned interchange both with the rail modes and ferries, and within the bus mode itself using purpose-built hubs. As a result passenger numbers have been significantly increased and long and unreliable routes have also been reduced to the benefit of service quality.

Automatic Vehicle Management

As noted above, the KentKart on-vehicle validator has always had an automatic vehicle location capability even though this wasn't activated in the initial application of the e-ticketing system. However, once that application had been completed in 2004, ESHOT and it's ITS system supplier then started to develop an automatic vehicle management system which was implemented progressively from 2006.

In its first phase, this just provided an on-line vehicle tracking capability. Each bus is 'polled' on a 10-second cycle, and its GPS location is then transmitted back to the operations control function; the cost of this GSM transmission is some €20 per bus per month.

This information was then used primarily for control of departure timings, especially at the outer terminals of routes where the level of supervision was necessarily low. However it also enables any route violations to be detected by cross-checking against the co-ordinates of the route to which the bus is currently assigned.

These data also allow for the speed of the vehicle to be calculated, which was then deemed to be of particular significance for the ancillary fleet. This information is now displayed on the buses, as part of the RTPI package, and a telephone contact number given for passengers to report inappropriate driving.

The vehicle location information is now reviewed on a route by route basis in order to examine the actual service headways being experienced, and identify whether any bunching is starting to occur. Should that be the case, then buses getting too close to the one in front are instructed to hold back and let the headway open out again. This is achieved by longer dwell times at stops and slower driving, with no special provision being made for hold-over points along the route.

Relatively little emphasis is placed on adherence to schedule, as it is not usually possible for a bus running late to make up time. As such, operations control actually increases delays for all vehicles on the route, and hence for all passengers who plan their trips according to the timetable. However vehicle loading may become more even as the headways are regularized and service quality is improved as a result.

The operations control centre at ESHOT was upgraded in 2009, but the company recognizes that this is still basically a reactive 'monitoring' unit rather than a proactive 'management' unit. The system integrator estimates that the current deployment of AVM is only reaching some 30% of its potential, and that there is thus a need for reform of operations management practices.

The next planned development, therefore, is to move the operations management information from the center down to the divisional hubs. Local managers will then be given authority for dynamic rescheduling, and the deployment of a 'hot reserve' for schedule restoration. In this manner, schedule restoration becomes a realistic objective as well as improved response to service disruptions. The main obstacle identified for this initiative, though, is the suitability of different sizes of buses for specific routes – and hence the scale of the reserve fleet that is required at each location.

However the operations control center does also link the surveillance functions, the emergency response capability, the communications network, and the internal efficiency control systems. As such, it will retain its importance for ESHOT even as the responsibility for operational control is devolved. The respective functions served by the center will be covered in later sections of this case-study.

The AVM system generates a range of reports for management information purposes. These include:

- Route violation report
- Daily total kilometer report
- Speed-band / time-duration graphic
- Speed violation report

- Schedule adherence report

Passenger Information Systems

ESHOT have developed real-time passenger information systems at two separate levels – at bus-stops, and on the bus itself. At this stage, the vehicle tracking information generated by the AVM is not posted on-line for dynamic route planning, and the website only hosts traditional route schedule information.

The basic data for the RTPI application are generated from the AVM vehicle tracking application, and the identification of the route variant that each bus is serving. The resultant information is transmitted to dot-matrix displays in the bus shelters, and these are configured so as to provide full data for the next two expected arrivals or summary data for the next four arrivals with the display toggling between these.

In each case the information display shows the identifying number of the route being served, and the number of stops away from the shelter that the nearest bus is currently positioned; the full data display adds the destination terminal of the route number in question. The displays can also show schedule changes, or any other summary information of importance to travelers.

The selection of the number of stops away, rather than the expected delay to arrival, was a pragmatic choice based on the impact of congestion in much of the network in which there is very little public-transport priority. It was felt better by ESHOT to give accurate information that could be interpreted by passengers, rather than more useful information that had the potential to frustrate if it proved to be inaccurate.

At the current time, the bus-stop information displays are still being rolled out in a pilot program with only a small minority of the nearly 6,000 shelters now being so equipped. Whether because of the restricted coverage, or because the information was not found to be of great value on the high frequency routes serving these shelters, observation suggests that the displays were generating little interest and that travelers still looked up the road for the arrival of their next bus.

Discussions confirmed that the information displays would have greater benefit on low-frequency routes in the periphery of the network, but that the required investment would be more difficult to justify under those circumstances where the numbers of travelers would be relatively small.

However there is also an enquiry service, whereby travelers are able to learn when a bus is expected to arrive at their stop, using a SMS text message via GPRS on their personal cell-phone. It is likely that this will form the predominant means of real-time passenger information in the peripheral areas for the foreseeable future.

The on-bus passenger information system comprises a 19” VGA color video screen on which a graphic of the route and its immediate surroundings is displayed. The screen shows the position of the bus in real time, and also its speed. Announcements are made concerning the current or approaching bus stop.

The system therefore provides on-vehicle route tracking for passengers, and enables them to prepare for alighting at the appropriate stop. However it doesn’t provide the expected time of arrival at the main interchange points along the route, which might be of concern to passengers intending to make a linked journey.

The passenger information unit can also provide news feeds and weather forecasts, and hence provides an 'infotainment' capability. Finally it provides point-of-contact details for ESHOT should passengers wish to provide personal feedback on driver behavior or standards.

Mobile Video Surveillance System

The MVS system at ESHOT consists of a mobile digital video recorder and wide-angle cameras appropriately located within the bus. The MVS system also takes vehicle tracking and speed data from the AVL capability of the smart-card validator. Finally the GPRS communications capability links the collected data through to the operations control centre when needed.

The recorder is provided with a smart memory card that can be used to take visual evidence of an incident into secure keeping for any subsequent investigation or prosecution. It also has ports for the downloading of data as required for management information purposes, and for direct GPRS wireless transmission if required.

The primary function of the MVS system is integrated recording of AFC transactions in order to identify the perpetrators of any attempted fraud. However this system also provides some deterrent protection against attacks on the driver in that visual evidence is captured. In the event of an attack, a driver emergency button connects the incident direct to the control centre for a rapid support response.

From an operations management perspective, the MVS system provides for the recording of any traffic incidents and collisions, including deceleration sensors to identify the severity of the impact. It also monitors the boarding and alighting of passengers and any disturbance at the shelter while the bus is stationary. This surveillance provides personal security, and helps to protect ESHOT from any spurious claims for damages.

ITS-Facilitated Functions

ESHOT also uses the data generated by it's ITS systems in order to improve the overall effectiveness and efficiency of its service delivery, as summarized below.

The automated fare collection system, and its integrated automatic vehicle location function, provides a wealth of data about individual travel patterns in terms not only of origins and destination but also of points of interchange. These enable the recasting of the bus-service network in response, and to improve integration with the other transport modes in the metropolitan area.

The automatic vehicle location function enables measurement of travel times, and their variations (both by time of day and direction of travel), between nodes within the bus network. In this manner bus schedules can be made more achievable, and any vulnerabilities be detected for management intervention. Dynamic rescheduling is now planned under decentralized operations management.

The ESHOT fuel management system takes data directly from the driver card onto a reader at the pump so as to allocate issues to the appropriate vehicle, and to upload the kilometers run by the bus into the system; this avoids any transcription errors that are typical of manual systems. The data link from the pumps to the control center also carries the stock levels in the bulk-fuel tanks, and integrates with the re-ordering function. Exception reports are generated that can identify drivers or buses with abnormal fuel consumption rates.

Finally, the kilometers operated by each bus are also used to inform the preventive maintenance function and to schedule planned interventions accordingly.

Benefits arising from the ITS systems at ESHOT

The achieved/perceived benefits of the ITS investments at ESHOT are viewed separately for the automated fare collection system, and for the various other ITS applications. Benefits of the ITS systems have not been quantified, and it does not appear that it was felt necessary to do so. In the case of the AFC system, the benefits are regarded as self-evident; in the case of the other applications, the systems are mostly still under development and haven't reached their full potential.

However the system integrator has a close working relationship with ESHOT, and is developing its applications in response to the emerging needs of the operator. By meeting those expectations, it has secured two contract renewals since the initial AFC award.

For the fare collection system, the main benefits reported are:

- Improved revenue generation through reduction of fraud and peculation
- Elimination of cash handling, security and administration costs of traditional paper tickets
- Accelerated fleet investment, enabled by improved operating cash flow
- Greater network efficiency arising from planned interchange, enabled by the through-ticketing capability and elimination of transfer charging
- Increased ridership as a result of the network integration, though this is of more significance to the rail-based modes

For the other ITS applications, the main benefits reported are:

- Improved operational control, though in a reactive rather than proactive sense
- Improved real-time passenger information, especially on-board the bus
- Enhanced security through on-board video surveillance
- Generation of data on service performance, and their incorporation into more accurate schedules
- Automation of data collection for management information and preventive maintenance scheduling

7.4 Ahmedabad, India[6]

Overview

Public transport in Ahmedabad is provided by AMTS buses. The basic concept is that the City provides an excellent operating environment, and AMTS should operate on-time services within that frame.

- The ITS is integral to the Ahmedabad's public transportation facility and to the organization, business processes, operating procedures, data, and management. The approach has matured over a period of time as they gain better understanding of what they can do, embed it in the organization, and evolve the technology.

[6] Source: UNEP, CEPT

- BRTS - An affordable public transport network that enables people to reach their destinations in the shortest possible time, in the easiest possible manner, was implemented in 2009.
- The urban mobility plan provides choices to the people in the case of their mobility, in terms of different modes such as the AMTS, BRTS and the suburban rail or metro, all of which complement each other.
- BRTS has evolved from using ITS to just know where their vehicles are, to precision operation with on-time running and transfer assurance
- Passenger information is extremely well-developed, prior to the trip, at stops and in the vehicles. It provides a seamless and ubiquitous guidance.

Scope of the case study

This case study deals with the ITS implemented at Ahmedabad through implementation of BRTS system named 'Janmarg', the public bus operator in the designated areas of Ahmedabad.

It does not cover the ITS implemented at the rail or other private bus operators, or any ITS at the small number of other operators of urban bus services, except where this is directly relevant to the ITS implemented at BRTS - Ahmedabad. It does not cover ITS implemented by the city for traffic management or other transportation services, again except where it is relevant to or interfaces with the Ahmedabad BRTS ITS (in particular the real-time information).

Context

The city of Ahmedabad is a historic city established in 1411 A.D on the eastern banks of the river Sabarmati. Since the times of its inception, it has been a centre for trade and commerce. It is well-known for its cotton-textile industry and was called the "Manchester of the East". Ahmedabad, a commercial capital of Gujarat, is one of the key emerging urban centres of India. The Ahmedabad Municipal Corporation (AMC) covers an area of 466 sq.km (2012) with a population of 5.5 million (as per provisional Census, 2011).

Ahmedabad started its Municipal Transport service (AMTS) in 1947, which is now one of the oldest urban transport organizations in the country. Its operations started with 112 buses (Central Institute of Road Transport, 1996, p. 1). AMTS is under the supervision and control of the AMC. A study by the Central Institute of Road Transportation in 1996 stated that at that time the AMTS had a bus fleet of 724, operating on 187 routes and carrying 0.62 million passengers daily with a yearly revenue of `475.93 million (USD 10.58 million). The fleet utilization rate of the system was between 80 and 83 per cent (Central Institute of Road Transport, 1996).

Ahmedabad has a long planning history, wherein encouraging ITS, developing road network and infrastructure precede urban development. Effective transportation planning mechanism through the ITS has enabled compact structure of the city and a complete hierarchical road network of the city, along with this a transport network that is aligned strategically in order to cover the entire city and bring about intensified development and urban regeneration are best practices in order to integrate the planning of transportation.

Motivation to implement ITS in Ahmedabad

The Government of Gujarat had declared 2005 the 'Year of Urban Development' (Shaheri Vikas Varsh). During this particular year, the urban development department undertook various initiatives to resolve urban issues such as traffic management, and the introduction and enhancement of a city transport system. The Gujarat Infrastructure Development Board (GIDB), AMC and Ahmedabad Urban Development Authority (AUDA) jointly drafted a comprehensive urban mobility plan keeping in mind the needs of Ahmedabad as a mega city, and included in it, the implementation of the Bus Rapid Transit System (BRTS) and the planning of the regional rail and metro for future years.

CEPT University was assigned the work of the preparing of a Detailed Project Report (DPR) for the implementation of the BRTS project in Ahmedabad. Meanwhile, the government of India announced the Jawaharlal Nehru National Urban Renewal Mission (JNNURM) for urban development and the AMC submitted its proposal to the government of India for the BRTS project, which was the first of its kind in the country. As approved by the ministry of urban development, the AMC is now implementing the BRTS project in a phased manner.

The BRTS project was approved in November 2006 and work on the project commenced in 2007.

Applications for which ITS is used at BRTS - Ahmedabad

The various components/applications which forms part of the ITS implementation for Bus Rapid Transit system in Ahmedabad are:

- Bus based Automated Fare Collection System
- Bus based GPS based Fleet Monitoring System
- Bus based Passenger Information System
- Bus based Vehicle Scheduling & Dispatch System
- Financial Management System / Central Clearing House System
- Bus based Depot Management System
- Business Intelligence
- Enterprise Management System

Management and oversight of ITS system

At least 50 per cent of the financial assistance has been provided by the Government of India, and the rest has to be managed by the cities and the states. In 2011, 9 cities in India had received funds under JnNURM for construction of BRTS and there are operational BRT corridors of various sizes and types in the cities of Ahmedabad, Jaipur, Vizag, Pune and Delhi.

Ahmedabad has the largest operational BRTS corridor to date and is growing. It is now seen as an example by other cities to learn from its preliminary success. The city's BRT system, known as "Janmarg", was started in the year 2009, and it has attracted global as well as national awards as a prime example of best practice in the field of public transport. Two years have passed since the opening of the first corridor, and Janmarg is now operating along a 44.5 km route and carrying about 0.15 million passengers with a daily revenue of about 0.75 million (Ahmedabad Municipal Corporation, 2011). It is expected to become a path-bearer for many other cities in India. Janmarg means 'People's Pathway', and this study will assess whether this definition of 'people' is inclusive and whether it has indeed become an important option for public transport in the city.

Janmarg: Ideology and system design

Ahmedabad BRTS is provided with an Integrated Transportation Management System (IMTS) which includes Advanced Vehicle Tracking System (AVLS), Fleet Management System (FMS), Automatic Fare Collection System (AFCS), Passenger Information System (PIS), Passenger announcement (PA), and Vehicle Scheduling and Dispatching (VSD). These technologies have been provided by the Spanish company GMV Innovating Solutions. The ITMS is currently operated since 2010 by a JV lead by GMV Innovating Solutions. Ahmedabad BRTS has received several national and international awards for its ITMS, such as the National Award for "Award for Excellence in the category of Best Project – 2011" from Government of India.

The BRTS corridor was designed by following the ideology of connecting busy places but avoiding busy roads. This ideology played a strong part in how the first corridor was selected for design and implementation by the AMC. The first implemented corridor of Phase-I from RTO to Chandranagar was laid out on the inner ring road in the western part of the city, which had an existing road width of 40 m and manageable traffic volumes of 3,000-6,000 PCU (Passenger Car Unit) on most of the stretch and 6,000- 9,000 PCU elsewhere. This decision also facilitated the smooth arrival of the BRTS in Ahmedabad, unlike in other cities such as Delhi and Pune where the system had to bear severe criticism from personal motor vehicle users. The first corridor in Ahmedabad did not create problems for private vehicle users because it returned back a similar amount of road space, and also provided a good service to regular bus users.

This was a good public relations exercise for the new system. The other major points which planners of Janmarg had in mind were "Designing a Network and not a corridor". This mistake has been made by many cities that have visualized the projects in terms of corridors and not a network. Janmarg was the first BRT Project which aimed at creating a city-wide network within the first proposal, rather than delineating corridor by corridor. This approach also helped them to realize the project in the context of the city, rather than specific roads. It was decided to create a project on the lines of Bogotá's Transmilenio, with median bus lanes and NMT facilities along the BRT lanes. The BRTS implementation was carried out in two phases.

Bus Lane and bus station design

The BRT lanes in both phases have railings on two sides, and guide the pedestrians to crossroads only at specific locations where zebra crossing has been provided. The station is built in the middle of the bus lane. In Phase-I, the width of the bus lane is 7.0 m in all ROWs. Service lanes of 7.0 m width have been provided on the two sides, just after the bicycle track on the 60 m ROW. Parking space of minimum width of 2 m has also been provided at all ROWs except at the 30 m ROW. The width of the mixed-traffic lane decreases with the ROW. The width of the footpath varies from 2.0 m to 2.2 m and of bicycle tracks from 2.0 m to 2.25 m. Bicycle tracks are segregated on ROWs of 40 m and above as well as for ROW of 30 m, but non-segregated for ROW of 36 m.

In Phase-II, bus lane width has been increased by 300-500 mm, and it is 7.3 m at the 30 m ROW and 7.5 m at the 36 m and 40 m ROWs. This was done mainly to leave more space between two buses when they pass each other on the corridor. The minimum width of mixed-traffic lane is 6.0 m on both sides at the 30 m ROW, and increases to 8.25 m at the 40 m ROW. Parking has been provided in all

ROWs ranging from 2.1 m to 2.3 m, which is more in width as compared to Phase-I. Although segregated bicycle tracks of 2.4 m have been provided at the 40 m ROW, at the 36 m ROW they are not segregated and are of slightly lesser width. No separate bicycle track has been provided at the 30 m ROW. The width of the footpath has been improved in Phase-II and it ranges between 2.5 m to 2.7 m.

Bus stops are planned roughly at every 700 m. There are two kinds of bus stops. The longer ones are made of concrete and look more like permanent structures. There are also smaller ones which are made of steel and look more temporary in nature. There is a stark difference between the two kinds of bus stations. Longer concrete bus stations can cater to two buses per direction at a time, and the steel bus stops can cater to one bus per direction at a time. Each bus stop is provided with a ramp to make it easier for the physically challenged and those in wheelchairs, to move. The bus stations are airy and well lit. A passenger information system is provided by digital display boards, which constantly updates the time and destination of the expected bus. Station doors are automated and open in sync with the bus door. Bus stops are 900 mm above the ground, and therefore level-boarding to the bus is smooth and easy for physically challenged and elderly people. The reasons for the deviation in bus stop design is not clear, but prima facie it seems that bus stations near slums and residential areas of low income groups in Eastern Ahmedabad were made of steel due to possible fear of vandalism.

Ahmedabad's BRT system is the only one in India in which fares are collected at the bus stops. This has obviously reduced chaos in buses, made the boarding-alighting easier and reduced the possibility of fare evasion, but on the other hand has rendered the collection of separate fares for air-conditioned (AC) and non-AC buses impossible. Still, there is just one fare for AC and non-AC buses, while AJL pays different charges per km to the operator for AC and non-AC buses. Display boards at bus stops also do not indicate if the arriving buses are AC or non-AC, which also makes the possibility of buying a separate ticket for AC buses at the ticket window impossible. There is no clarity regarding how a different fare for an AC bus would be deducted from a smart card while making an exit from the bus stop.

Operations Management

Janmarg's buses are privately owned and operated. Currently there is just one bus operator working with AJL, but more will be joining as soon as the system extends to its full length. Janmarg uses Euro III and Euro IV compliant diesel engines, high-floor (90 cm) buses, a decision which was taken due to the much higher cost of the low floor buses. CNG buses are now slowly being added to the fleet, and the new ones would all be CNG. There are 78 buses with the AJL right now, out of which 10 are AC buses. AJL has a gross cost contract designed to include incentives and penalties to govern operations. AJL is currently paying ` 43.11 per km to the private operator which was earlier ` 34.11 (Indian Express, 2012). The design of the buses is such that it has a door 900 mm above the ground level to match it with the Janmarg bus station on one side, and a low door on the other side. The bus has a seating capacity of just 36 people, and hence ensures more standing room.

Buses

It has a mixed fleet of air conditioned and non-air conditioned buses. Parts for the buses are provided by Tata Motors. These buses are built by Chartered Speed locally according to specifications.

Benefits arising from ITS

Within four months of start of operations, positive impacts of the system have been visible.

Increase in Ridership: Ridership has increased consistently. Average daily passengers have increased from 17,315 (first month) of launch to 1, 50,000+ (Aug 2014). Frequency of service is at 2.5 and 4 minutes peak during weekdays. Ridership has gone upto 1,50,000+/day.

Improvement in travel speed: Peak hour speed- 26kmph as opposed to 16-18 kmph of Ahmedabad Municipal Transport Service. Average speeds of mixed traffic same as BRTS on most stretches.

Dependable Service/Reliability: Over 95% to 97% of departures are on time.

Increase in Revenues: As a result of increased numbers, with 161 buses operating, revenue per bus increased from ` 4500 to ` 10,240+ per bus per day (Aug 2014).

Modal shift: During the first month, of the total BRTS users, 57% were AMTS bus users. Now this has come down to 40%. Major shifts are from 3-wheelers (25%), 2wheelers (20%) and Cars (10%). Shifts from bicycles are not significant. (2010)

Environment: Due to expansion of bus system, both through AMTS and BRTS< and conversion of AMTS and Auto Rickshaws to CNG, significant improvements in air quality have been observed. From a position 3rd most polluted among the 88 critically polluted cities monitored by CPCB, the city has come down to a level of 66th rank. (2010)

Economic Social Impacts: Two types of social impacts are visible. The routes of BRTS network went through the areas inhabited by the poor. Improved accessibility would not only contribute to widening of the employment market of the poor and also add to physical up gradation of the area. There are visible signs of these impacts in certain localities. System wide impacts, to become visible, will take some more time. Land value impacts are also visible. Several project schemes now advertise their location in the BRTS corridor as major marketing strategy.

User Satisfaction: Surveys have shown, BRTS got average rating of 9.0 out of 10 in the eleventh month from its users, which is in tune with the past months of commercial operation. Survey asks for input on safety while crossing the streets, operator driving, frequency of service, ease of fare payment and cleanliness at stations.

Information Availability: Real Time passenger information is made available at the stations. Announcements are in English and Gujarati.

7.5 Curitiba, Brazil[7]

Overview

- The bus system of Curitiba, Brazil, exemplifies a model Bus Rapid Transit system, and plays a large part in making this a livable city.
- The buses run frequently some as often as every 90 seconds and reliably, commuters ride them in great numbers, and the stations are convenient, well designed, comfortable, and attractive.
- Curitiba has one of the most heavily used, yet low cost, transit systems in the world. It offers many of the features of a subway system vehicle movements unimpeded by traffic signals and congestion, fare collection prior to boarding, quick passenger loading and unloading but it is above ground and visible.
- Even with one automobile for every three people, one of the highest automobile ownership rates in Brazil, and with a significantly higher per capita income than the national average, around 70 percent of Curitiba's commuters use transit daily to travel to work.
- Greater Curitiba with its 2.2 million inhabitants enjoys congestion free streets and pollution free air.

Scope of the Case Study

This case study deals with the ITS implemented at Curitiba through the implementation of BRTS system. The case study provides information related to the bus system that was implemented in Curitiba and the processes followed by them. It also mentions how the integration of transit with the existing infrastructure, was performed, and the benefits of ITS implementation through bus system therein.

It does not cover the ITS implemented at other private bus operators, or any ITS at the small number of other operators of urban bus services, except where this is directly relevant to the ITS implemented at Curitiba. It does not cover ITS implemented by the city for traffic management or other transportation services, again except where it is relevant to or interfaces with the Curitiba Bus system.

Context

Curitiba is the capital city of the State of Parana in Southern Brazil. The city is located about 250 kilometers [150 miles] southwest of Sao Paulo near the coastal mountain range. Current data (mid-1990s) shows a population of some 1.6 million distributed within city limits of about 430 square kilometers [165 square miles] and a total metropolitan area population of some 2.2 million. The city has a thriving economy with the gross domestic product reported at $7,827 (U.S. dollars) per head in 1997, among the highest of any city in South America.

Automobile ownership has been variously reported: it was between 295 per 1000 in 1997and perhaps 500 per 1000 in 1999. During the 1960s to early 1980s, Curitiba grew at a rapid rate, with a population growth rate of approximately 4% per year. Although a city plan had been prepared in the

[7] Source: ITS Applications in Developing countries: A case study of Bus Rapid Transit and Mobility Management Strategies in Dar es Salaam

middle of the 1940s, the plan failed to recognize the issues raised by the need to deliver urban services to a rapidly increasing demand caused by population and economic growth, within a realistic level of investment.

By applying intelligent transport systems (ITS) in urban environments, cities were able to move towards the smart city model and achieve a more efficient and sustainable mobility. This contributes towards reducing traffic congestion and the resulting direct and indirect costs, minimizing contaminating emissions and promoting the use of urban transportation. It is a model that improves the quality of life of citizens.

Overview of ITS implementation in Curitiba through bus system

The bus system of Curitiba, Brazil, exemplifies a model Bus Rapid Transit system, and plays a large part in making this a livable city. The buses run frequently some as often as every 90 seconds and reliably, commuters ride them in great numbers, and the stations are convenient, well designed, comfortable, and attractive.

Key features of the bus system include the following:

- Physically separated median bus lanes flanked by two local service streets;
- 26 mid-route and end-of-line terminals for transfer among bus takers;
- An integrated fare structure;
- “Tube” stations with off-vehicle fare collection and platform boarding of buses;
- “Direct” express service in the parallel one-way arterials; and
- Distinctly colored bi-articulated buses (see Figure 4) along the busway, each with five doors and designed for level (“high-platform”) boarding at tube stations.

Curitiba’s median busways have been progressively expanded over the last 30 years. The first 20 km [12.4 miles] were planned in 1972, built in 1973, and placed in service in 1974. In 2001, there were 40 km [37 miles] of busway along the five structural axes.

A trunk and feeder bus system operates in which buses are routed through a series of terminals where passengers transfer between busway vehicles, feeder routes, and interdistrict links with no further payment of fares. Buses, which are operated by private companies under municipal supervision, use a common color-coding system.

Motivation to implement ITS in Curitiba

The Curitiba plan follows an integrated approach to development of transport facility.

Key directions are the following:

- Promotion of a linear urban city growth by integrating public transport and road network development, along key, “structural axes”;
- (Traffic) decongestion of the city center and preservation of the historic central city core;
- Management and control of land use citywide;

- Provision of economic support incentives to urban development to realize land use aims and to assist employment generation; and
- Improvement of infrastructure.

Bus system for which ITS is currently used in Curitiba

The bus system did not develop overnight, nor was it the result of transit development isolated from other aspects of city planning. It exists because thirty years ago Curitiba's forward thinking and cost conscious planners developed a Master Plan integrating public transportation with all elements of the urban system. They initiated a transportation system that focused on meeting the transportation needs of the population rather than focusing on those using private automobiles and then consistently followed through over the years with staged implementation of their plan. They avoided large scale and expensive projects in favour of hundreds of modest initiatives. A previous comprehensive plan for Curitiba, developed in 1943, had envisioned exponential growth of automobile traffic and wide boulevards radiating from the central core of the city to accommodate the traffic. Rights of way for the boulevards were acquired, but many other parts of the plan never materialized.

With the adoption of the new Master Plan in 1965, the projected layout of the city changed dramatically. The Master Plan sprang from a competition among urban planners prompted by fears of city officials that Curitiba's rapid growth, if non-channelled, would lead to the congested, pedestrian unfriendly streets and unchecked development that characterized their neighbour city, São Paulo, and many other Brazilian cities to the north. As a result of the Master Plan, Curitiba would no longer grow in all directions from the core, but would grow along designated corridors in a linear form, spurred by zoning and land use policies promoting high density industrial and residential development along the corridors. Downtown Curitiba would no longer be the primary destination of travel, but a hub and terminus. Mass transit would replace the car as the primary means of transport within the city, and the high density development along the corridors would produce a high volume of transit ridership. The wide boulevards established in the earlier plan would provide the cross section required for exclusive bus lanes in which express bus service would operate.

This backbone service, aptly described as Bus Rapid Transit, is characterized by several features that enable Curitiba's bus service to approach the speed, efficiency, and reliability of a subway system: integrated planning ; exclusive bus lanes ; signal priority for buses ; Pre - boarding fare collection ; level bus boarding from raised platforms in tube stations ; free transfers between lines (single entry) ; large capacity articulated and bi-articulated wide door buses ; and overlapping system of bus services. Each artery is composed of a "trinary" road system, consisting of three parallel routes, a block apart. The middle route is a wide avenue with "Express" bus service running down dedicated high capacity express bus ways in the center two lanes, offering frequent stop service using standard, articulated and bi - articulated buses carrying up to 270 passengers a piece. The outer lanes are for local access and parking. Back in the 1960s the building of a light rail system in these avenues had been considered, but proved to be too expensive. The two outer routes are one way streets with mixed vehicle traffic lanes next to exclusive bus lanes running "direct" high speed bus service with limited stops. Both the express and direct services use signal priority at intersections.

Buses running in the dedicated and exclusive lanes stop at tube stations. These are modern design cylindrical shaped, clear walled stations with turnstiles, steps, and wheelchair lifts. Passengers pay their bus fares as they enter the stations, and wait for buses on raised station platforms. Instead of steps, buses are designed with extra wide doors and ramps which extend when the doors open to fill the gap between the bus and the station platform. The tube stations serve the dual purpose of providing passengers with shelter from the elements, and facilitating the efficient simultaneous loading and unloading of passengers, including wheelchairs.

A typical dwell time of only 15 to 19 seconds is the result of fare payment prior to boarding the bus and same level boarding from the platform to the bus. Passengers pay a single fare equivalent to about 40 cents (U.S.) for travel throughout the system, with unlimited transfers between buses. Transfers are accomplished at terminals where the different services intersect. Transfers occur within the prepaid portions of the terminals so transfer tickets are not needed. In these areas are located public telephones, post offices, newspaper stands, and small retail facilities to serve customers changing buses. Ten private bus companies provide all public transportation services in Curitiba, with guidance and parameters established by the city administration. The bus companies are paid by the distances they travel rather than by the passengers they carry, allowing a balanced distribution of bus routes and eliminating the former destructive competition that clogged the main roads and left other parts of the city unsaved. All ten bus companies earn an operating profit. The city pays the companies for the buses, about 1 percent of the bus value per month. After ten years, the city takes control of the buses and uses them for transportation to parks or as mobile schools. The average bus is only three years old, largely because of the recent infusion of newly designed buses, including the articulated buses, into the system.

Management and Oversight of bus system with the help of ITS

BUSWAY TRACK

The Curitiba busways are located along “structural axes” that comprise three roads, the central one of which is a busway and service-access road. Busways are continuous along five corridors or structural axes with a total length of 58 km. Busway characteristics are the following:

- The track is used exclusively by trunk line buses.
- The track is separated from other service-access traffic by continuous physical islands or by island bus stop platforms.
- Busway crossings with other roads are generally at grade and signal controlled (it is believed bus traffic signal actuation exists).
- The track is located in the center of the bus and service-access road, and thus, the busway-road, unlike many attempted adaptations of the “Curitiba principle” in other cities, is not a major traffic-carrying route. Passenger access to/from stops does not involve crossing through dense, possibly fast moving traffic.
- The curb-to-curb envelope contains eight lanes; it is about 26 meters [85 feet] wide.
- Tube stations preempt the parking lanes adjacent to the busway.

PASSENGER FACILITIES

Passenger facilities along the busway structural axes/corridors are of three types:

- "Tube" stops, which equate to conventional bus stops and are located at spacing of about 450 to500 m along the 58 km of busways;
- Interchange-integration terminals at the out-of-city end of each of the five structural axes/corridors to permit trunk-feeder bus interchange; and
- Mid-route, smaller terminals at key points, about 2-km spacing, along each busway corridor to permit trunk-feeder bus interchange.

Tube Stops

The "tube" passenger stop platforms or stations are the trademark of the Curitiba system. They can serve three times as many passengers per hour as a conventional bus. "Tube" stops are used both on the trunk line busways and on the express buses (off the busway).

Stop details are as follows:

- On busways, tube stops are located at about 500-m [0.3-mile] spacing.
- The tubes include raised platforms (low-floor buses are not in operation) and provide passenger weather protection; the stops are constructed from a plexiglass-type material with steel ribs.
- The tube stops are equipped with doors to enter/exit buses; these are coordinated with doors on the buses – five doors on the trunk line bi-articulated buses (and two on express buses).
- Disabled and wheelchair access to the high-level stops is made through a small elevator at each stop
- Passenger boarding and alighting of buses is gap free and level; this is achieved by the use of fold-down steps from bus doors, which deploy automatically as bus doors are opened and position onto the threshold of the platform (see Figure 9); it is understood that bus-platform positioning door-to-door is done visually by the driver, and there is adequate tolerance to ensure safe operation of the system;
- The stops are designed to speed passenger handling, and fares are paid by passengers at the entry to the stop – similar to a metro. Each stop is equipped with turnstiles (numbers depend on size of stop) and are manned by a ticket collector–inspector
- On busways, tube stops are on line with no special provision for bus-on-bus overtaking. Theoretically, the busway is wide enough to allow overtaking by buses entering the opposing bus stream, but this is not normal operational practice.
- Stops for both directions are generally located opposite each other and close to junctions. As stops are located on the central road of the trinary axes, access and traffic issues are less critical than on a busway introduced into an existing road. However, as with any stop, there is a need to balance safety, junction capacity, and busway capacity.

SERVICE AND OPERATIONS

Curitiba's "bus rapid transit" system includes trunk line buses operating on the busways as "express" services and "direct" services operating on the adjacent one-way arterial streets. Feeder buses serve the arterial trunk lines on the five structural axes/corridors, but they are not given priority over other traffic.

Express Service

The "express" services are segregated from other traffic. Shops are located every 500 meters [1,640 feet] and integrated terminals every 4 kilometers [2.5 miles]. They are reported to operate at a headway of 90 seconds during the peak periods.

Direct Service

"Direct" express bus services run along the one-way roads on each side of the central roads that form the structural axes. These services feature fewer stops, and passengers pay before boarding the buses in special raised tubular stations. The service was initiated in 1991 with four routes that parallel the busways. By 1995, there were 12 lines that served more than 225,000 daily trips.

Fare Collection

The "tube" stops and integration terminals are planned to avoid all fare collection on buses. Payment of fares at stops (which applies to the express services off the busway as well as the busway services) is at a manned turnstile at the stop entrance. Clearly, this has labor cost implications, and smart card fare payment systems are scheduled for imminent introduction. No data are available on fare avoidance, but the "tube" entry system and the integration terminals (Which are manned by inspectors at the bus entry to prevent passengers attempting to enter without payment) appear to be secure systems.

Benefits of BRT system in Curitiba

The popularity of Curitiba's Bus Rapid Transit system has affected a modal shift from automobile travel to bus travel, in spite of Curitibanos' high income and high rate of car ownership relative to the rest of Brazil. Based on 1991 traveller survey results, it was estimated that service improvements resulting from the introduction of Bus Rapid Transit had attracted enough automobile users to public transportation to cause a reduction of about 27 million auto trips per year, saving about 27 million litres of fuel annually. In particular, 28 percent of direct bus service users previously travelled by car. Compared to eight other Brazilian cities its size, Curitiba uses about 30 percent less fuel per capita, because of its heavy transit usage. The low rate of ambient air pollution in Curitiba, one of the lowest in Brazil, is attributed to the public transportation system's accounting for around percent of private trips in the city. Residential patterns changed to afford bus access on the major arteries to a larger proportion of the population. Between 1970 and 1978, when the three main arteries were built, the population of Curitiba as a whole grew by 73 percent, while the population along the arteries grew by 120 percent. Today about 1,100 buses make 12,500 trips per day, serving more than 1.3 million passengers per day, 50 times more than 20 years ago. Eighty percent of the travellers use either the express or direct bus service, while only 20 percent use the conventional feeder services. Plans for extending the rapid bus network will reduce the need for conventional services. In addition to enjoying speedy and reliable service, Curitibanos spend only about 10 percent of their income on travel, which is low relative to the rest of Brazil.

The toolkit on "Intelligent Transport System" provides an overview of applications and technologies to be used for public transportation services and Bus Rapid Transit Systems for the relevant cities that envisage the use of ITS in their respective cities and its relevance in investments and financing decisions. It also looks into implementation phases and key elements that needs to be focused on that will aid the stakeholders in investment analysis processes and the decisions relating to existing process changes required, if any, as a path towards technology advancement in public transport services thereby leading to enhanced customer satisfaction and standard of living. The target audiences for this toolkit are the agencies involved in decision-making like local authorities involved in planning and implementation of projects and, consultants/ institutions supporting project design or advising the government on transactions.

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