Intelligent Transportation Systems (ITS)

Overview

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Key ITS Projects

- Mysore ITS, KSRTC
- Indore ITS, AICTSL
- Hubli-Dharwad ITS, HDBRTSCO
- VTMS, KSRTC
- Bhubaneswar Smart City, BSCL
- CTU CBMP, CTU
- PCMC M&E, Pimpri-Chinchwad
- Hyderabad ITMS, Hyderabad Police
- Chennai ITS, CSCL
- Hyderabad Adaptive Signals, GHMC
- ADB TOD & MMI, BMRCL
1. Introduction
“Transportation is the movement of goods and persons from place to place and the various means by which such movement is accomplished.”
Is this Transportation?
Is this Transportation?

Source: https://thewire.in/
Is this Transportation?
Community Evolution

1970: The City of Individual Bits and Pieces
- Focus on specialization, efficiency and productivity
- Users/Citizens: Public Meetings

1990: The Increasingly Interconnected City
- Focus on sustainability, integration and participation
- Users/Citizens: Shared Mobility

2010: The Responsive and Resilient City
- Focus on collaboration, user experience and quality of life
- Users/Citizens: Experience-centered, Proactive, Adaptable

Source: IBI Group
What is ITS?

• ITS provides a way to resolve a variety of road traffic issues, such as traffic accidents and congestion, by linking people, roads, and vehicles in an information and communications network via cutting-edge technologies.
Other Definitions of ITS

1. ITS has as its primary objective increasing system efficiency and safety through the use of set of tools, techniques, technology, standards, and best practices.
   • Traffic Engineering, Roger P. Roess, Elena S. Prassas, William R. McShane

2. ITS is an operational system of various technologies that, when combined and managed, improve the operating capabilities of the overall system
   • History of ITS Book, FHWA-JPO-16-329, USDOT

3. Application of sensing, analysis, control and communications technologies to improve the safety, efficiency, and sustainability of transportation networks.
ITS Evolution

KEY MILESTONES IN THE HISTORY OF INTELLIGENT TRANSPORTATION SYSTEMS

Pre-1980s

1980s

1990s

2000s

2010s

Source: https://www.its.dot.gov/
Why ITS?
Why ITS?

Source: https://www.timesnownews.com/
Why ITS?
Why ITS?
Why ITS?

Source: https://timesofindia.indiatimes.com/
Why ITS?
Why ITS?
ITS extends across

Research  Planning  Design  Integration  Deployment
Multimodal

Facility Types

- Highways
- Arterials
- Fixed guideways
- Bikeways
- Sidewalks
- Multimodal facilities
- Ports and terminals

Auto (car)
Transit
Freight
Bicycles
Pedestrians
ITS Benefits

- Improved safety
- Reduced congestion
- Reduced emissions
- Reduced travel times
- Enhanced access and quality of life
- Crash prevention
- Cost savings for commercial vehicle operations
ITS Benefits

- Achieve Efficiency Through Application of Technology:
  - Livability
  - Safety
  - Governance
  - Capacity
  - Cost
  - ...
Systems we discussed

• Incident Management System
• Advanced Public Transport Systems
• Road Weather Information Systems
• Emergency Vehicle Planning
• Parking Management Systems
• Traveler Information Systems
2. ITS Systems & Devices
Key ITS Systems

- Advanced Transportation Management Systems (ATMS)
  - Integrated Traffic Management System (ITMS)
  - Advanced Traveler Information Systems (ATIS)
  - Road Weather Information Systems (RWIS)
- Advanced Public Transit Systems (APTS)
- Advanced Commercial Vehicle Operations Systems
- Advanced vehicle control systems
Key ITS Systems

- Advanced Traffic Management Systems (ATMS)
- Advanced Traveler Information Systems (ATIS)
- Advanced Vehicle Control Systems (AVCS)
- Commercial Vehicle Operations (CVO)
- Intelligent Public Transit Systems (IPTS)
- Advanced Parking Management Systems (APMS)
- Cooperative Intelligent Transport Systems (C-ITS)
• Advanced Traffic Management Systems (ATMS)
  • These systems use sensors and communication technologies to monitor traffic conditions and provide real-time traffic information to drivers, traffic operators, and transportation agencies.

- Traffic Control Centers
- Automatic Vehicle Counting and Classification Systems (AVCC)
- Traffic Signal Control Systems (TSC)
- Incident Management Systems (IMS)
- Ramp Metering
- Dynamic Message Signs (DMS)
- Dynamic Lane Merge Systems (DLMS)
- Speed Management Systems
- Red Light Camera System
- Portable Changeable Message Signs (PCMS)
- Congestion Pricing & Toll Systems
• Advanced Traveler Information Systems (ATIS)
  • These systems provide travelers with real-time information about traffic conditions, alternative routes, and transportation options such as public transit and ridesharing.
• Advanced Vehicle Control Systems (AVCS)
  • These systems use sensors and communication technologies to help vehicles navigate through traffic, avoid collisions, and reduce congestion.

- Adaptive Cruise Control (ACC)
- Lane Departure Warning (LDW)
- Automatic Emergency Braking (AEB)
- Blind Spot Detection (BSD)
- Forward Collision Warning (FCW)
- Electronic Stability Control
- Adaptive Headlights
- Parking Assistance
- Vehicle-to-Vehicle (V2V) Communications

• AVCS vs. Advanced Driver Assistance Systems (ADAS)
• Commercial Vehicle Operations
  • These systems use technologies such as GPS, electronic toll collection, and automatic vehicle location to improve the safety and efficiency of commercial transportation.
Intelligent Public Transit Systems

- These systems use advanced technologies to improve the safety, efficiency, and convenience of public transportation, such as automatic fare collection, real-time passenger information, and vehicle tracking systems.

- Automatic Vehicle Location (AVL) systems
- Passenger Information Systems (PIS)
- Automated Fare Collection Systems (AFCS)
- Fleet Management Systems
- Safety & Security Systems
- On-board Technologies
• Advanced Parking Management Systems
  • These systems use sensors and communication technologies to provide real-time parking information to drivers, improve parking management, and reduce congestion.

- Parking Guidance and Information Systems (PGIS)
- Automatic Vehicle Counting and Classification (AVCC) Systems
- License Plate Recognition (LPR) Systems
- Payment and Access Control Systems
- Parking Reservation Systems
- Remote Monitoring & Management Systems
Cooperative Intelligent Transport Systems

- These systems enable vehicles, infrastructure, and other devices to communicate with each other and exchange information, which can improve safety, reduce congestion, and enhance mobility.
ITS Systems - Example-1
ITS Systems - Example-3
ITS Systems - Example-4
ITS Systems - Example-5

Source: USDOT.
ITS Systems - Example-9
ITS Systems – SAE Automation Levels

**SOCIETY OF AUTOMOTIVE ENGINEERS (SAE) AUTOMATION LEVELS**

<table>
<thead>
<tr>
<th>Level</th>
<th>Automation Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>No Automation</td>
<td>Zero autonomy; the driver performs all driving tasks.</td>
</tr>
<tr>
<td>1</td>
<td>Driver Assistance</td>
<td>Vehicle is controlled by the driver, but some driving assist features may be included in the vehicle design.</td>
</tr>
<tr>
<td>2</td>
<td>Partial Automation</td>
<td>Vehicle has combined automated functions, like acceleration and steering, but the driver must remain engaged with the driving task and monitor the environment at all times.</td>
</tr>
<tr>
<td>3</td>
<td>Conditional Automation</td>
<td>Driver is a necessity, but is not required to monitor the environment. The driver must be ready to take control of the vehicle at all times with notice.</td>
</tr>
<tr>
<td>4</td>
<td>High Automation</td>
<td>The vehicle is capable of performing all driving functions under certain conditions. The driver may have the option to control the vehicle.</td>
</tr>
<tr>
<td>5</td>
<td>Full Automation</td>
<td>The vehicle is capable of performing all driving functions under all conditions. The driver may have the option to control the vehicle.</td>
</tr>
</tbody>
</table>
Devices that detect and measure physical parameters such as traffic volume, speed, and vehicle classification, among others. These sensors provide data that is used by transportation agencies and operators to improve the safety, efficiency, and sustainability of transportation systems.
Devices – Detectors/Sensors: Types

- Inductive Loop Detectors
- Video Cameras
- Radar and Lidar Sensors
- Infrared Sensors
- Ultrasonic Sensors
- Bluetooth & Wifi Sensors
Devices – Detectors/Sensors: Classification

• Based on implementation
  • Intrusive
    • Installation of sensing system affects existing infrastructure – pavement work (loop detectors, pneumatic tubes)
  • Nonintrusive
    • Installation does not impede traffic flow (RFID and VIPS technology)
  • Off-Roadway
    • Sensor not fixed on the roadway (GPS receivers, cell phones, helicopters, and satellites)

• Based on function
  • Mobile Sensors
    • Inbuilt to each individual vehicle (GPS receivers, acoustic/ultrasonic sensors, Bluetooth)
  • Point Sensors
    • Mounted at fixed locations along the roadway and observes traffic only at this particular location (Inductive Loop detectors, pneumatic tubes, RFID technology)
  • Space Sensors
    • Ability to take snapshots of traffic across space (Helicopter/Satellite photography)
Devices – Detectors/Sensors: Applications

<table>
<thead>
<tr>
<th>Source</th>
<th>Tools</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smart Card</td>
<td>Smart Card</td>
<td>OD Flows, Travel Time</td>
</tr>
<tr>
<td>GPS</td>
<td>GPS</td>
<td>Vehicle Position, Vehicle Density, Vehicle Speed</td>
</tr>
<tr>
<td>Video</td>
<td>Video Camera</td>
<td>Vehicle Position, Vehicle Speed, Vehicle Density, Vehicle Classification</td>
</tr>
<tr>
<td>Road Site Sensor</td>
<td>Induction Loops, Road Tubes, Microwave Radar, LIDAR/Infrared Acoustic, Toll Plazas</td>
<td>Vehicle Position, Vehicle Speed, Vehicle Density, Vehicle Classification</td>
</tr>
<tr>
<td>Floating Car Sensor</td>
<td>License Plate, Transponders</td>
<td>Travel Time, OD Flows</td>
</tr>
<tr>
<td>Wide Area Sensor</td>
<td>GPS, Cell phone Tracking, Airborne Sensors</td>
<td>Travel Time, OD Flows</td>
</tr>
<tr>
<td>Connected and Autonomous Vehicles (CAVs)</td>
<td>Diverse Sensors</td>
<td>Coordinate, speed, acceleration, safety data,</td>
</tr>
<tr>
<td>Passive Collection</td>
<td>Social Media, Phone Data</td>
<td>Travel Time, OD Flows</td>
</tr>
<tr>
<td>Other Sources</td>
<td>Smart Grid, Smart Meters, Cellular Service, Dedicated Tests</td>
<td>Electric and Energy Consumption, Location, Channel Data</td>
</tr>
</tbody>
</table>
Transportation Systems Management and Operations (TSMO) typically involves integrating a range of strategies, technologies, data, and partnerships, and a mindset to determine the best way to optimize the mobility and reliability of the existing system with limited resources.

This approach integrates TSMO throughout agency processes and includes involvement from other units such as planning and design and other programs such as safety and construction.

It also engages external partners such as metropolitan planning organizations, local agencies, and incident responders.
The Challenge

I'm not talking to you!!

Well I'm not talking to you either

Traffic Signal Controllers

Source: DRCOG, 2006
The Challenge

- Communications
- BDC
- LED Destination Display
- IP Cameras
- Validator
- Speakers & Microphone
- CAN Bus (Multiplex)
ITS Architecture – Definition

• The ITS architecture provides common framework for planning, defining and integration ITS systems. It specifies how different ITS components interact with each other to help solve the transportation problem.

• It is the conceptual design that defines the structure and/or behaviour of the system.

• Benefits
  • Interoperability
  • Information Exchange
  • Resource Sharing
  • Security
USA - ITS Regional Architecture
USA – Revised ITS Architecture

• Architecture Reference for Cooperative and Intelligent Transportation (ARC-IT)

• Link: https://www.arc-it.net/
Architecture Diagrams - AVLS

- GPS Satellite
- Data Center
- Wired Network
- TMC
  - AVL Dispatcher WS
  - IVR System
- Commuter website
- ETA at Mobile
- GSM/GPRS network
- Bus with OBITS Equipment
- PIS at Terminals/Bus Stations
- Depot System
HGS ITS Example

<table>
<thead>
<tr>
<th>Year</th>
<th>Fatal</th>
<th>Grievous injury</th>
<th>Minor injury</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Year 2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Year 3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Total</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>
## HGS ITS Example: Benefits at the Single Junction

### Accident Severity

<table>
<thead>
<tr>
<th></th>
<th>Fatal</th>
<th>Grievous</th>
<th>Minor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents (Jan 2007 – Sep 2009)</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Cost/Accident (Rupees)</td>
<td>7,00,000</td>
<td>3,00,000</td>
<td>50,000</td>
<td></td>
</tr>
<tr>
<td>Accidents Cost (Jan 2007 to Sep 2009)</td>
<td>14,00,000</td>
<td>15,00,000</td>
<td>45,00,000</td>
<td>74,00,000</td>
</tr>
</tbody>
</table>

### For 20 Years

| Assume Accident Reduction in Year 1* | 1     | 1      | 3     | 5     |
| Accident Savings in Year 1          | 7,00,000 | 3,00,000 | 1,50,000 | 11,50,000 |
| Assume Accident Reduction in 20 years* | 10    | 20     | 30    | 60    |
| Accident Savings for 20 Years       | 70,00,000 | 60,00,000 | 15,00,000 | 1,45,00,000 |
| ITS Year 1 Costs                   |       |        |       | 48,80,000 |
| ITS Life-Cycle Costs               |       |        |       | 66,80,000 |

FYRR \(100 \times \frac{\text{Savings in Year 1}}{\text{Initial cost}}\) = 100×91,68,158/52,80,000 = 174  
Life-Cycle Benefit-Cost = Savings for 20 years/Life Cycle Cost = 9,33,77,024/66,00,000 = 14
## ARC-IT: Service Packages

<table>
<thead>
<tr>
<th>Area</th>
<th>Short Name</th>
<th>Name</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Commercial Vehicle Operations</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CVO01</td>
<td>Carrier Operations and Fleet Management</td>
<td></td>
</tr>
<tr>
<td>CVO02</td>
<td>Freight Administration</td>
<td></td>
</tr>
<tr>
<td>CVO03</td>
<td>Electronic Clearance</td>
<td></td>
</tr>
<tr>
<td>CVO04</td>
<td>CV Administrative Processes</td>
<td></td>
</tr>
<tr>
<td>CVO05</td>
<td>Commercial Vehicle Parking</td>
<td></td>
</tr>
<tr>
<td>CVO06</td>
<td>Freight Signal Priority</td>
<td></td>
</tr>
<tr>
<td>CVO07</td>
<td>Roadside CVO Safety</td>
<td></td>
</tr>
<tr>
<td>CVO08</td>
<td>Smart Roadside and Virtual WIM</td>
<td></td>
</tr>
<tr>
<td>CVO09</td>
<td>Freight-Specific Dynamic Travel Planning</td>
<td></td>
</tr>
<tr>
<td>CVO10</td>
<td>Road Weather Information for Freight Carriers</td>
<td></td>
</tr>
<tr>
<td>CVO11</td>
<td>Freight Drayage Optimization</td>
<td></td>
</tr>
<tr>
<td>CVO12</td>
<td>HAZMAT Management</td>
<td></td>
</tr>
<tr>
<td>CVO13</td>
<td>Roadside HAZMAT Security Detection and Mitigation</td>
<td></td>
</tr>
<tr>
<td>CVO14</td>
<td>CV Driver Security Authentication</td>
<td></td>
</tr>
<tr>
<td>CVO15</td>
<td>Fleet and Freight Security</td>
<td></td>
</tr>
<tr>
<td>CVO16</td>
<td>Electronic Driver Logs</td>
<td></td>
</tr>
<tr>
<td>CVO17</td>
<td>Intelligent Access Program</td>
<td></td>
</tr>
<tr>
<td>CVO18</td>
<td>Intelligent Access Program - Weight Monitoring</td>
<td></td>
</tr>
<tr>
<td>CVO19</td>
<td>Intelligent Speed Compliance</td>
<td></td>
</tr>
<tr>
<td>CVO20</td>
<td>International Border Registration</td>
<td></td>
</tr>
<tr>
<td>CVO21</td>
<td>International Border Electronic Clearance</td>
<td></td>
</tr>
<tr>
<td>CVO22</td>
<td>International Border Coordination</td>
<td></td>
</tr>
<tr>
<td><strong>Data Management</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DM01</td>
<td>ITS Data Warehouse (implementations)</td>
<td></td>
</tr>
<tr>
<td>DM02</td>
<td>Performance Monitoring (implementations)</td>
<td></td>
</tr>
</tbody>
</table>
Institutional - Standards and Protocols

Traffic Signal Controller

Source: DRCOG, 2006
**Highlights**

**TVDS**
- License plate number detection
- Identify stolen/ suspected vehicles
- Over Speed detection up to 150km/hr.
- Integration with Vahan and RTO
- Integration with Smart City Platform

**ATCC**
- Thermal Technology
- Non intrusive Technology
- Detection up to 4 Lanes / camera
- High Uptime, Reliable & Scalable
- No wear & tear
- Integrated with Smart City Platform

**TARS**
- Easy RCA
- Isolating common features in accident

**Deployment**

- 25
- 93
- 20

**Benefits**
- Reduced peak hour congestion
- Enhanced Traffic planning
- Safety & Air quality
- Traffic updates to citizens
- Coordinated management

**Architecture**

**Source:** IBI Group
3. ITS & Road Safety
**Accident or Crash**

**Accident**

ˈaksɪd(ə)nt

*noun*

an unfortunate incident that happens unexpectedly and unintentionally, typically resulting in damage or injury.

**Crash**

/kraʃ/

*noun*

a *violent collision*, typically of one vehicle with another or with an object.
Policy Decision

- Walking
- Cycling
- Public transport
- Private cars

Source: schaeffler.com
Overview – Road Safety Statistics

37 DEATHS PER 100 CRASHES

No. of accidents (in lakh)

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of accidents</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>4.8</td>
</tr>
<tr>
<td>2017</td>
<td>4.5</td>
</tr>
<tr>
<td>2018</td>
<td>4.5</td>
</tr>
<tr>
<td>2019</td>
<td>4.4</td>
</tr>
<tr>
<td>2020</td>
<td>3.5</td>
</tr>
</tbody>
</table>

No. of deaths

<table>
<thead>
<tr>
<th>Year</th>
<th>No. of deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>1,51,801</td>
</tr>
<tr>
<td>2017</td>
<td>1,50,093</td>
</tr>
<tr>
<td>2018</td>
<td>1,52,780</td>
</tr>
<tr>
<td>2019</td>
<td>1,54,732</td>
</tr>
<tr>
<td>2020</td>
<td>1,33,201</td>
</tr>
</tbody>
</table>

Deaths per 100 accidents (approx)

<table>
<thead>
<tr>
<th>Year</th>
<th>Approx Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>2016</td>
<td>32</td>
</tr>
<tr>
<td>2017</td>
<td>34</td>
</tr>
<tr>
<td>2018</td>
<td>34</td>
</tr>
<tr>
<td>2019</td>
<td>35</td>
</tr>
<tr>
<td>2020</td>
<td>37</td>
</tr>
</tbody>
</table>

Source: National Crime Records Bureau

Source: Timesofindia.com
Overview – Accident Major Contributors

- Speeding
- Dangerous Driving
- Weather
- Alcohol
- Driving when Tired
- Non-use of Helmet/Seatbelts
- Mobile Usage & Poor Visibility
- High beam
Key Crash Causes by Categories

- Human Error
  - Over Speeding
  - Drunk Driving
  - Distracted Driving
  - Red-light Jumping
  - Wrong-way Driving
  - Merging & Weaving
  - Reckless Driving through Junctions

- Mechanical Failures

- Weather

- Infrastructure Limitations
Frequently Recommended Safety Measures

Frequently used short-term measures

• Signboard
• Rumble strip
• Solar Blinker
• Junction
• Road markings
• Pedestrian crossing
• Road studs/cat-eye
• Bar marking
• Speed limit
• Speed breaker

Frequently used long-term measures

• Median opening
• Close the median
• Providing junction Elevated/flyover
• Providing underpass
• Widening
• Speed control measures
When considering a group of four accidents at a location, the 'chains of events' are unique overall.

Source: RoSPA
The clustering of accidents is indicative of the possibility that one or more of the road and environment factors may well be links which are found in several of the 'chains of events'.

Source: RoSPA
Identify Common Factors – Road, Environment, Driver - that lead to the crash

Source: RoSPA
Situation - 1
Situation-1: ITS Solution?
Situation-2
Situation-3
4. ITS Case Study - Highway Safety

Halol-Godhra-Shamlaji Study
Halol-Godhra-Shamlaji (HGS) Highway Corridor

Vijay Kovvali
# HGS Highway Accident Cost

<table>
<thead>
<tr>
<th>Crash Severity</th>
<th>Fatal</th>
<th>Grievous</th>
<th>Minor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Based on Current Data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crashes/Year</td>
<td>98</td>
<td>117</td>
<td>129</td>
<td>344</td>
</tr>
<tr>
<td>Ratio</td>
<td>1</td>
<td>1.19</td>
<td>1.31</td>
<td></td>
</tr>
<tr>
<td>Cost/Crash (Rupees)(^1)</td>
<td>87,45,155</td>
<td>1,69,545</td>
<td>84,486</td>
<td></td>
</tr>
<tr>
<td>Total Cost/Year</td>
<td>85,70,25,169</td>
<td>1,98,36,744</td>
<td>1,08,98,694</td>
<td>88,77,60,607</td>
</tr>
<tr>
<td><strong>Based on Realistic Data</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio Estimated for India(^2)</td>
<td>1</td>
<td>15</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>Crashes/Year</td>
<td>98</td>
<td>1470</td>
<td>4900</td>
<td>8428</td>
</tr>
<tr>
<td>Cost/Crash (Rupees)(^1)</td>
<td>87,45,155</td>
<td>1,69,545</td>
<td>84,486</td>
<td></td>
</tr>
<tr>
<td>Total Cost/Year (Rupees)</td>
<td>85,70,25,169</td>
<td>24,92,30,885</td>
<td>41,39,81,400</td>
<td>1,52,02,37,455</td>
</tr>
</tbody>
</table>

\(^1\)IIT Madras Study, 2019
\(^2\)Road Safety in India: Status Report 2021, TRIP Centre

Current Crash Cost/Year for HGS = One hundred and fifty two crore Rupees
HGS Lifecycle Accident Cost Estimation

• Current Increase in Accidents on HGS Highway is 8%
  • Assume an average of 5% increase in accidents for the next 20 years

<table>
<thead>
<tr>
<th>Crash Severity</th>
<th>Fatal</th>
<th>Grievous</th>
<th>Minor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Crashes for 20 years @ 5% increase</td>
<td>3,399</td>
<td>50,963</td>
<td>1,69,881</td>
<td>2,24,243</td>
</tr>
<tr>
<td>Cost/Crash (Rupees)¹</td>
<td>87,45,155</td>
<td>1,69,545</td>
<td>84,486</td>
<td></td>
</tr>
<tr>
<td>Life Cycle Cost of Crashes</td>
<td>29,72,47,81,131</td>
<td>8,64,05,12,662</td>
<td>14,35,25,66,166</td>
<td>52,71,78,59,959</td>
</tr>
</tbody>
</table>

20 Year Crash Cost for HGS = Fifty two hundred crore rupees
ITS for HGS Corridor

**Standalone ITS Systems**
- Blinker Units
- Sparkle Studs
- Fixed Camera Enforcement
- Vehicle Actuated Signs

**Toll Systems**
- WIM
- Smart Cards
- Lane Signals
- Toll Collector Stations

**Recce & Recovery System**
- Medical Aid Post
- Traffic Aid Post
- Police
- Remote Workstation

**HTMS Systems**
- CCTV's
- Fixed VMS
- Mobile VMS
- Web Service
- SMS & Email
- Information Screens

**ITS Basic Architecture**
- Proposed
- Remote workstation
- Wired
- Wireless

**Other Systems**
- WIM
- CCTV's
- HTMS Systems
- Meteorological System
- ATCC
- ECN
- Journey Time Monitoring
- Automatic Incident Detection

**Text**
- Black Text - Existing System
- Red Text - New System
- Green Text - Additional Number Recommended for Existing System
### Yearly Traffic Accident Summary

<table>
<thead>
<tr>
<th>Year</th>
<th>Fatal</th>
<th>Grievous Injury</th>
<th>Minor Injury</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Year 1</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Year 2</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Year 3</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2</strong></td>
<td><strong>2</strong></td>
<td><strong>5</strong></td>
<td><strong>9</strong></td>
</tr>
</tbody>
</table>

**Notes:**
- Yearly statistics represent minor injuries, grievous injuries, and fatal accidents.
- The total number of accidents for the three-year period is 9.
• Vertical Curve a Challenge
  • Otherwise, design treatment is quite satisfactory
• Accident potential - high
• Sight distance for minor street vehicles
• Speed of highway vehicles
HGS ITS Example - Needs

- Reduce highway vehicle speeds
- Actively warn major/minor street vehicles only when a conflict exists
- Enforce speed on the stretch
HGS ITS Example - Treatments

• Reduce highway vehicle speeds
  • Active: Rumble Strips, Change in Road Surface, etc.
    • 3D Speed Breakers: Good or Bad?
HGS ITS Example - Treatments

• Reduce highway vehicle speeds: Passive ITS
HGS ITS Example - Treatments

• Reduce highway vehicle speeds: Active ITS
• Actively warn major/minor street vehicles only when a conflict exists
HGS ITS Example - Treatments

• Speed Enforcement
## HGS ITS Example: Cost of ITS System

<table>
<thead>
<tr>
<th>Item</th>
<th>Number</th>
<th>Life-Cycle Number*</th>
<th>Cost/Unit</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITS Application</td>
<td>1</td>
<td>4</td>
<td>1,00,000</td>
<td>4,00,000</td>
</tr>
<tr>
<td>Speed Display</td>
<td>2</td>
<td>4</td>
<td>3,00,000</td>
<td>12,00,000</td>
</tr>
<tr>
<td>Vehicle Activated Sign</td>
<td>2</td>
<td>4</td>
<td>1,20,000</td>
<td>4,80,000</td>
</tr>
<tr>
<td>Speed Enforcement Camera</td>
<td>2</td>
<td>4</td>
<td>7,50,000</td>
<td>30,00,000</td>
</tr>
<tr>
<td>Installation Cost</td>
<td>1</td>
<td>1</td>
<td>2,00,000</td>
<td>2,00,000</td>
</tr>
</tbody>
</table>

**Capital Cost**

1. 52,80,000

**O&M Cost @ 25% of Capital Cost**

1. 13,20,000

**ITS Life Cycle Cost**

1. 66,00,000
# HGS ITS Example: Benefits at the Single Junction

<table>
<thead>
<tr>
<th>Accident Severity</th>
<th>Fatal</th>
<th>Grievous</th>
<th>Minor</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accidents (Jan 2007 – Sep 2009)</td>
<td>2</td>
<td>5</td>
<td>9</td>
<td>16</td>
</tr>
<tr>
<td>Cost/Accident (Rupees)</td>
<td>7,00,000</td>
<td>3,00,000</td>
<td>50,000</td>
<td></td>
</tr>
<tr>
<td>Accidents Cost (Jan 2007 to Sep 2009)</td>
<td>14,00,000</td>
<td>15,00,000</td>
<td>45,00,000</td>
<td>74,00,000</td>
</tr>
</tbody>
</table>

**For 20 Years**

<table>
<thead>
<tr>
<th>Assume Accident Reduction in Year 1*</th>
<th>1</th>
<th>1</th>
<th>3</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accident Savings in Year 1</td>
<td>7,00,000</td>
<td>3,00,000</td>
<td>1,50,000</td>
<td>11,50,000</td>
</tr>
<tr>
<td>Assume Accident Reduction in 20 years*</td>
<td>10</td>
<td>20</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>Accident Savings for 20 Years</td>
<td>70,00,000</td>
<td>60,00,000</td>
<td>15,00,000</td>
<td>1,45,00,000</td>
</tr>
</tbody>
</table>

| ITS Year 1 Costs                   | 48,80,000 |
| ITS Life-Cycle Costs               | 66,80,000 |

**FYRR (100 * Savings in Year 1/Initial cost) = 100*91,68,158/52,80,000 = 174**

**Life-Cycle Benefit-Cost = Savings for 20 years/Life Cycle Cost = 9,33,77,024/66,00,000 = 14**
5. ITS Deployment Guidance
ITS Deployment Steps

Transportation Needs

Budget

ITS Architecture

Project-Specific ITS Solutions

ITS Technologies

Transportation Improvements

Safety, Economic & Community Benefits
ITS (Safety) Technologies

- Active Body Control
- Adaptive Cruise Control
- Advanced Driver Assistance System (ADAS)
- Adaptive Front Steering and Active Body Control
- Adaptive Traffic Signal Control Installations
- Alcohol (inter) lock
- Anti-Collision Systems
- Automated Enforcement of Traffic Rules
- Automated incident detection
- Black Box
- Bridge or Tunnel Control
- Connected vehicles
- Dynamic Route Information Panels
- Dynamic Traffic Management
- e-Call
- Electronic Stability Program or Control
- Event or Crash Data Recorder
- Fatigue Detectors
- Incident Management
- Intelligent Speed Adaptation (ISA)
- Intersection Signal Control
- Inter-vehicle Hazard Warning
- Lane Departure Warning
- Lane Keeping Assistant
- Lateral Control Systems
- Local Danger Warning
- Navigation Systems
- Network signal Control
- Obstacle & Crash Warning
- Park Guidance Systems
- Radio Data System
- Ramp Metering or Control
- Real-time Travel and Traffic Information Services
- Route Guidance Systems
- Road Traffic Information Services
- Seat Belt Reminders
- Speed Alert
- Speed Enforcement
- Telematic Speed Recommendations
- Traffic and Incident Management Systems
- Traffic Control Centers
- Traffic Message Channel
- Traffic Sign Recognition and Alert
- Urban Drive Assistant
- V2x technologies
- Variable Message Signs
- Variable Speed Limit Signs
- Vision Enhancement
- Weather-Related Traffic Management
1. ITS Process – Detailed Project Report

- Identify Stakeholders
- Gap & Needs Analysis
- ITS Solutions & Potential Project Systems
- Concept Plans & Architectural Diagrams
- Business Process Re-engineering
- Costing & Financial Analysis
- Recommendation
2. ITS Key Stakeholders

- End Customer
- User Departments
- Public
- Project Management Consultant
- System Integrator
2. ITS Key Stakeholders – Hyderabad Signaling Project

- GHMC
- Osmania University
- IBI Group
- Traffic Police – Hyderabad, Cyberabad, Rachakonda
- Public
3. ITS Needs Analysis - HDBRTSCO

ITS Project Needs Analysis

ITS Functional Needs Analysis - Stakeholders
- HDBRTSCO
- NWKRTC
- Traffic Police
- Commuters
- KRDCI/PWD
- HDMC

ITS Functional Needs Analysis - Infrastructure
- BRT Corridor
- Junctions
- BRT Stations
- Feeder Station
- BRT Trunk Bus
- BRT Feeder Bus
- City Mobility Centre (TMC)
- Terminals
- Depot

ITS Functional Needs Analysis - Operations
- Trunk & Feeder Services
- Express & Regular Trunk Services
- Station Configuration
- Transfers between Systems
- Service & Frequency Planning
- Delays at Junctions
- Dwell Time at Bus Stations
- Bus Station Location
- Alternate/ Additional Revenue
- Operational Cost

Source: IBI Group
3. ITS Needs Analysis – Chennai | Data
3. ITS Needs Analysis – Chennai | Data Visualization

497 Junctions Surveyed & Shortlisted
(Topographic Survey)

Based on 408 Police Traffic Signal List

165 Junctions Prioritized
(Phase-1 Priority Corridors + Support Junctions)

145 Signals in Police List

Source: IBI Group
3. ITS Needs Analysis – Chennai | Traffic Counts
3. ITS Needs Analysis - Chennai | Data

ACCIDENTS IN PHASE1 AREA

- Around 23% of the total accidents occurs in Phase-1 area with a fatality rate of 14%.
- Chennai CBD area under Phase-1 section witnesses highest number of accidents.
- Majority of accidents occurs in areas like Triplicane and Adyar followed by T. Nagar, Saidapet and Anna Nagar which carries high volume of traffic.

Source: IBI Group
3. Needs Analysis – Chennai Bus | Other Projects

1. NEXT STOP ANNOUNCEMENT
   Passenger announcement system through PPP model.

2. LAMB PROJECT
   JICA has full-scale Fleet Management System – 4000 buses

3. NIRBHAYA SAFE CITY
   JICA has 1000 units for in-bus Surveillance, hence scope is removed from JICA.

4. KFW FUNDING
   300 electric buses, PIS, Depot Modernization & e-Governance: Consultant shortlisting under progress

5. DEPOT/TERMINAL MODERNIZATION
   16 Depots + Terminals – Transaction Advisor bid under progress
   2 Depots - Ambatture and Avdi – Under request

6. KIOSK
   15 Bus Terminals – Procurement under progress

7. ETM + COMMON MOBILITY CARD
   Government Order (GO) released

8. DMS APPLICATION + ROUTE RATIONALIZATION
   Currently not part of on-going or planned effort, but discussed by MTC in meetings

Source: IBI Group
## 3. Needs Analysis – Chennai Bus | Other Projects

<table>
<thead>
<tr>
<th>Project</th>
<th>Conflicting components</th>
<th>Applicability of solution implemented in respective projects</th>
<th>Benefits of solution in CITS over other projects</th>
</tr>
</thead>
<tbody>
<tr>
<td>ICCC</td>
<td>VMS</td>
<td>• VMS used for commercial purposes 80% of the time</td>
<td>• Traffic information share as per location of existing ICCC VMS.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Real-time traffic data and traffic detouring might not be possible</td>
<td></td>
</tr>
<tr>
<td>FMWS</td>
<td></td>
<td>• Only sensors proposed with CCTV for CCC alert management.</td>
<td>• ITS system can take input and use for traffic management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Data not disseminated to the road user</td>
<td></td>
</tr>
<tr>
<td>CCTV</td>
<td></td>
<td>• Location and camera not as per traffic requirement</td>
<td>• Meant for traffic merging locations for monitoring and incidence management</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Primary concern crime &amp; suspected activity</td>
<td></td>
</tr>
<tr>
<td>Safe City</td>
<td>CCTV</td>
<td>• CCTV location and usability not as per traffic requirement.</td>
<td>• Traffic monitoring and regulation using video analytics</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Primary concern crime &amp; suspected activity</td>
<td>• Near real-time incidence response.</td>
</tr>
<tr>
<td>Mega-Street</td>
<td>Junction improvement</td>
<td>• Comprehensive infrastructure work including geometric realignment, utility work etc.</td>
<td>• Limited to cosmetic improvement such as striping, pedestrian cross-walk etc.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Planned to compliment signals and peripheral ITS components</td>
</tr>
</tbody>
</table>
4. Needs Analysis – Chennai | Traffic

**Advanced Traffic Management**
- Integrated Traffic Management System (ITMS) Platform & Advanced Traveler Information System (ATIS) Platform
- Sensors (camera, ATCC, flood, environment, etc.)
- Service delivery (VMS, Apps, etc.)
- Future – v2i, v2v and other state-of-art technologies

**Design Interventions**
- Equitable intersection designs
- Markings
- Traffic calming where required
- User-expectancy based planning & design
- Last mile connectivity

**Incident Management**
- Surveillance (CCTV, etc.)
- Incident response
- Work zone management
- Integration with ATMS
- Integration with ATIS
- Integration with 112 & 108 systems

**Intelligent Signaling**
- Actuated + Adaptive signaling
- Central control
- Signal maintenance management
- Transit signal priority (TSP) capability
- Integration protocols with decision support systems

**Data Repository**
- Formats & standards
- Protocols
- Central repository with connected databases
- Open data portal with public access

**Education & Enforcement**
- Consistent enforcement
- Automated enforcement (RLVD, ANPR, e-challan, etc.)
- Relevant and comprehensive education programs
- Higher standards for obtaining driving license
- Point system for driving license vis-à-vis driver challans

Source: IBI Group
4. Needs Analysis – Chennai | Bus

**Control Room**
- Business Intelligence Application with Data Analytics
- Incident Management Application
- Video Wall & Workstations
- Helpdesk

**AVL System**
- On-board unit (GPS units)
- UBS-II & AIS-140 compliance
- AVL Central Fleet Management Software

**Surveillance**
- In-bus
- Terminal & other high-volume locations
- Depot, workshop and other internal facilities

**PIS System**
- In-bus announcement & display
- Mobile App
- Commuter Portal
- Displays at Terminals
- IVRS
- Kiosks at strategic locations

**ERP & Other Systems**
- Route rationalization
- Accounting & Finance
- Inventory
- Vehicle Scheduling & Rostering
- Human resource management
- Fuel management
- E-Governance

**AFCS System**
- ETM Machines with smartcard reading
- Common Payment Card
- Integration with route rationalization

Source: IBI Group

**Legend**

- **✓** MTC Immediate Needs
- **✗** Text in red not included in scope

### Control Room
- Business Intelligence Application with Data Analytics
- Incident Management Application
- Video Wall & Workstations
- Helpdesk

### Surveillance
- In-bus
- Terminal & other high-volume locations
- Depot, workshop and other internal facilities

### AVL System
- On-board unit (GPS unit) with bus display console
- ARIA certified On-board unit
- AVL Central Fleet Management Software

### PIS System
- In-bus display & announcement
- Mobile App
- Commuter Portal
- Displays at Terminals
- IVRS
- Kiosks at strategic locations

### ERP & Other Systems
- E-Governance
- Route rationalization
- Accounting & Finance
- Inventory
- Workshop
- Human resource management
- Fuel management

### AFCS System
- ETM Machines with smartcard reading
- Common Payment Card
- Integration with route rationalization
5. Standards & Protocols Understanding

Standards
Prescribed set of rules, conditions or requirements

Protocols
Set of rules or conventions formulated to control the exchange of data between two entities desiring a connection

• Benefits
  • Supports interoperability
  • Minimizes future integration costs
  • Facilitates regional integration
  • Supports incremental measurable development
  • Prevents technological obstacles
  • Minimizes operations and maintenance costs
  • Prepares for emerging technologies
  • Makes procurements easier
  • Makes testing easier
5. Protocols Understanding

- NTCIP Protocol for Traffic Signals?
- NMEA Protocol for AVL Data?

Source: DRCOG, 2006
6. System Architecture

• Provides a common framework for planning, defining, and integrating ITS

• The architecture defines:
  • The functions that are required for ITS
  • The physical entities or subsystems where these functions reside
  • The information flows and data flows that connect these functions and physical subsystems

• Architecture includes:
  • System architecture
  • Physical architecture
  • Data flow architecture
  • Logical architecture
  • Application architecture
6. National ITS Architecture - USA

Source: its.dot.gov
6. System Architecture - ITMS

ITMS Platform

- Generate and Confirm Events
- Manage & Close Events
- Insights & Actionable Intelligence
- Dashboard & Reporting
- Response Plan Implementation
- Retrieval System
- Interaction with Internal & External Systems/Users
- Scenario Analysis
- Business Intelligence
- Multi-Agency/System Co-Ordination

Multi-Agency Users
- Police
- Corporation
- Ambulance
- Fire
- Highways
- Media
- Citizens

Other ICT Projects/systems
- CPRR
- ICCC
- Safe City (Nirbhaya)
- Smart Parking
- Other transportation projects
- Other probe systems

Project Components
- Adaptive Traffic Signal
- Red Light Violation Detection
- Speed Limit Violation Detection
- Variable Message System
- Traffic Incident Detection
- Automatic Traffic Counter and Classifier
- CAD/AVL & Probe Data
- Mobile App/Web Portal
- Social Media Integration

Traffic Management Center

Within project scope
- Red Light Violation Detection
- Variable Message System
- Traffic Incident Detection
- Automatic Traffic Counter and Classifier
- CAD/AVL & Probe Data
- Mobile App/Web Portal
- Social Media Integration

External system integration
- Traffic Incident Detection
- Automatic Traffic Counter and Classifier

External system access
- Red Light Violation Detection
- Variable Message System
- Traffic Incident Detection
- Automatic Traffic Counter and Classifier
- CAD/AVL & Probe Data
- Mobile App/Web Portal
- Social Media Integration

E-CHALLAN
SMS
EMAIL
CHENNAI ITS

OTHER APPLICATIONS EXPECTED TO INTEGRATE

PROBE DATA
VIDS APPLICATION
SLVD APPLICATION

ATCS APPLICATION
ANPR APPLICATION
VMS APPLICATION

ATCC APPLICATION
RLVD APPLICATION
NETWORK/ENTERPRISE MANAGEMENT SYSTEM

DASHBOARD
EVENT MANAGEMENT
OPERATING PROCEDURE MODULE
DATA ACQUISITION MODULE
GIS MAP MODULE
REPORTING MODULE
INTEGRATION MODULE

INTERNAL MODULES OF ITMS APPLICATION

Source: IBI Group
7. System Architecture - Public Transport

- GPS Satellite
- GPS Signal
- Bus
- SCU & BDC
- GSM/GPRS Gateway
- Data Center
- LAN Network
- GSM/GPRS Gateway
- Broadband/Leased Line
- GSM/GPRS Gateway
- PIS at Terminals
- Dispatcher at Control Center
- Mobile Application
- Commuter Website
- Depot Management System

Source: IBI Group
7. System Architecture - Application

Unified Signal System (Central Module)
1. Show traffic signal locations / ITS devices on GIS Map
2. Show real-time signal staging & timing on map
3. Monitor health of signals
4. MIS & Dashboards

ITM5 Platform
- Provide ATCC data
- Emergency/VIP vehicle priority
- Handle traffic signal outage events
- BI dashboards/reports
- Traffic violation enforcement
- Third party crowd source data

Source: IBI Group
## 8. System Diagram

### Smart Traffic System
- Traffic Violation Detection Sub System Including RLVD
- ANPR Sub System
- Public Address System
- Dynamic Message Sign
- Network Flow (ATCC) and Congestion Monitoring System

### Smart Tracking System
- Public Transit CAD/AVL Solution
- Emergency Vehicle Management System
- Solid Waste Vehicle & Resource Tracking
- Municipal Vehicle Tracking
- Scheduling & Transit ERP
- Fare Collection System
- Passenger Information System

### Smart Parking
- On-Street Parking
- MLCP Parking
- Off-Street Parking
- Integration Parking Management Application

### Smart Response
- Surveillance System
- Emergency Call Boxes
- Emergency Contact Centre Systems

### Control Center
- Command & Control Centre
- ICOMC Platform
- E-Governance-ERP
- GIS Integration
- ICOMC - Interiors

### Other
- Fibe Optic Network
- WiFi Network
- Smart Poles
- Smart Education & Health
- Environmental Monitoring System

### Integration
- Existing Surveillance System
- Existing E-Governance/ERP
- Existing GIS Platform
- Existing Smart Street Lighting Project
- Traffic Signaling Project Under Procurement
- Common Payment System to be Procured
- Future SCADA Project
- Future PBS/E-Rickshaw Project
9. Business Process Re-engineering (BPR)

1. Organization Structure & Roles
2. Culture
3. Regulation & Incentive
4. Education & Training

1. Information Technology
2. Business Technology
3. Project Mgt. Technology

1. Simplification
2. Standardization
3. Workflow

Source: IBI Group
10. Defining Scope

- Silos or Integrated System?
- SaaS or On-Prem Application?
- State Data Centre or Project Data Centre?
- Power Backup Hours?
- Communication Network – Leased or Owned?
- Technology Quality?
- PTZ Cameras or Fixed Cameras?
- Closed Loop Card or Open Loop Card?
- How many Control Rooms?
- Timelines?

- Market Scan & Understanding
- Solution Provider or System Integrator or Vendor?
- Balanced Contract
- Public Private Partnership? Years?
- Payment Terms?
- Least Cost or Quality-Cost-Based Selection (QCBS)?
12. Specifications - Local vs. Mature Technologies

There is a sweet spot for mature technology where performance and cost to support are favorable.

Source: sketchbubble.com
12. Specifications - Public vs. Google Data
12. Specifications – Functional vs. Technical

• Functional vs. Technical Specifications
• Functional Specification
  • The display board shall be visible from 30 meters
• Technical Specification
  • Board size: 8,000 mm (W) x 3,000 mm (H)
  • Pitch shall be <= 10 mm

14. Realistic Project Timelines

**PROJECT TIMELINE**

**MILESTONE 1**
- Contracts
- Project Team

Proposal
01/01/2021

**MILESTONE 2**
- Design
- Project Team

Award Date
15/02/2021

**MILESTONE 3**
- Procurement
- Contractor

Documents Review
01/02/2021

Feasibility Study
01/03/2021

**MILESTONE 4**
- Delivery
- Contractor

Applying for Permits
15/03/2021

Commence Design
01/05/2021

Order Equipment
10/07/2021

**STAGE 1**

Order Materials
12/07/2021

**STAGE 2**

Deliver Project
30/12/2021

Source: powerslides.com
15. Implementation

- System Requirement Specification
- Design Documents
- Project Plans
- Prototype Acceptance
- Factory Acceptance Tests
- Pilot Implementation
- Pilot Acceptance
- System Acceptance Tests
- Operational Acceptance
16. Business Intelligence

Source: Nippon Koei and IBI Group
17. Stakeholder Capacity & Willingness
18. Monitoring & Evaluation

ARE WE ON COURSE?

HERE'S THE LATEST EVALUATION...

THE PROJECT
18. Monitoring & Evaluation

Remember M&E information is useful only if it is used!
**Monitoring**: Observe and check the progress or quality of the system over a period of time.

**Evaluation**: Act of determining the impact and setting a course of action.
18. Monitoring & Evaluation - Benchmarks

Source: Alamy stock photos

Source: Timeofindia.com
## 18. Monitoring & Evaluation – Performance Indicators

### PCMC BRT System Monitoring & Evaluation (M&E) Framework

<table>
<thead>
<tr>
<th>Category</th>
<th>Goal</th>
<th>Measure</th>
<th>S.No</th>
<th>Indicator</th>
<th>Coverage</th>
<th>Data Type</th>
<th>Source of Data</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Congestion</strong></td>
<td>To improve the modal characteristics of public transportation</td>
<td></td>
<td>1</td>
<td>Modal Share</td>
<td>Mixed Traffic</td>
<td>Primary</td>
<td>Traffic Vol. &amp; Occupancy Counts, HH Surveys &amp; PMPML Ops. Data</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>2</td>
<td>Average Trip Lengths</td>
<td>Mixed Traffic</td>
<td>Primary/Secondary</td>
<td>Transit Rider Survey and Household Survey &amp; ITS Components</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>3</td>
<td>Average Trip Rates</td>
<td>Including &amp; Excluding Walk</td>
<td>Primary</td>
<td>Household Survey</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>4</td>
<td>Travel Speeds</td>
<td>BRT, Bus, Mixed Traffic</td>
<td>Primary/Secondary</td>
<td>Speed Delay Survey, Spot Speed Survey, Vehicle Tracking System</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>5</td>
<td>Driving Times</td>
<td>BRT, Bus, Mixed Traffic</td>
<td>Primary/Secondary</td>
<td>Speed Delay Survey, Vehicle Tracking System</td>
</tr>
<tr>
<td><strong>Public Transport and NMT Attractiveness</strong></td>
<td>To make PT and NMT modes more attractive compared to private modes by offering high quality of service</td>
<td></td>
<td>6</td>
<td>BRT Ridership ~</td>
<td>BRT</td>
<td>Secondary/Primary</td>
<td>PMPML Operations Data, Gender Split Surveys</td>
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<td>Door to Door Journey Time</td>
<td>BRT, Bus</td>
<td>Primary/Secondary</td>
<td>Transit Rider, Boarding &amp; Alighting, HH Surveys, Vehicle Tracking System</td>
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<td>Schedule Adherence ~</td>
<td>BRT, Bus</td>
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<td>Vehicle Tracking (ITS), PMPML Operations Data</td>
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<td>NMT Users</td>
<td>Cyclists and pedestrians</td>
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<td>NMT volume Counts at Mid-blocks &amp; Intersections</td>
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<td>Quality of NMT Paths</td>
<td>Pedestrians, Cyclists</td>
<td>Primary</td>
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<td>Customer Satisfaction</td>
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<td>Commuter Satisfaction</td>
<td>BRT, Bus, NMT</td>
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<td>Transit Rider Surveys</td>
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<td>12</td>
<td>Inclination to Shift to BRT</td>
<td>Mixed Traffic, Bus</td>
<td>Primary</td>
<td>Household Surveys</td>
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<tr>
<td><strong>Environment</strong></td>
<td>To reduce travel induced environmental impacts</td>
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<td>Registered Vehicles</td>
<td>All motorised modes</td>
<td>Secondary</td>
<td>Road Transport Authority Data</td>
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<td>Fuel consumed/ passenger Km</td>
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<td>Passenger Km/litre of fuel</td>
<td>BRT, Mixed Traffic</td>
<td>Secondary</td>
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<td>CO₂ Emissions</td>
<td>Illustrative nodes on BRT corridors</td>
<td>Primary/Secondary</td>
<td>Traffic volume Counts at Mid-blocks &amp; Intersections</td>
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Source: IBI Group
## 18. Monitoring & Evaluation – Performance Indicators

### PCMC BRT System - Monitoring & Evaluation (M&E) Framework

<table>
<thead>
<tr>
<th>Category</th>
<th>Goal</th>
<th>Measure</th>
<th>S.No</th>
<th>Indicator</th>
<th>Coverage</th>
<th>Data Type</th>
<th>Source of Data</th>
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<tr>
<td>Multi Modal Integration</td>
<td>To Efficiently integrate private, NMT &amp; public transport modes</td>
<td>Modal Integration</td>
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<td>Access Modes to PT</td>
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<td>Number of Parking Locations</td>
<td>BRT, Bus</td>
<td>Primary/Secondary</td>
<td>Parking Inventory survey, BRT Corridor DPR’s by PCMC</td>
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<td>Safety</td>
<td>To increase road safety</td>
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<td>Number of Accidents/km</td>
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<td>Fatalities on BRT Corridor/km</td>
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<td>Economic &amp; Financial Viability</td>
<td>To make BRT service economically &amp; financially viable</td>
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<td>Operational Cost/km</td>
<td>BRT, Bus</td>
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<td>Operational Cost/Passenger</td>
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<td>Earnings Per Kilometre (EPK)</td>
<td>BRT, Bus</td>
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<td>Earnings Per Passenger (EPP)</td>
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<td>Revenue to Operating Cost Ratio</td>
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<td>Profit to Cost Ratio</td>
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<td>Fleet Utilisation</td>
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<td>Bus Occupancy Ratio</td>
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<td>Primary/Secondary</td>
<td>Vehicle Occupancy Surveys, PMPML Operations Data</td>
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<td>Passengers per operated km</td>
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<td>Land-use and TOD Impacts</td>
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<td>Property Values</td>
<td>Along the BRT Corridors</td>
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<td>Property Websites</td>
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<td>Rental Values</td>
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<td>Street Network Connectivity</td>
<td>Representative BRT Stations</td>
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<td>Google Maps</td>
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<tr>
<td>Technology</td>
<td>To implement technology for increasing reliability, efficiency and productivity</td>
<td>ITS System</td>
<td>32</td>
<td>ITS System Availability</td>
<td>BRT</td>
<td>Secondary</td>
<td>ITS System Reports</td>
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<td>ITS Usage</td>
<td>33</td>
<td>ETA/ETD Accuracy</td>
<td>BRT</td>
<td>Primary/Secondary</td>
<td>Transit Rider Surveys, Field Observation, ITS System Reports</td>
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<td>Transit Data Accessibility</td>
<td>BRT</td>
<td>Secondary</td>
<td>ITS System Reports, Web Page Hits, SMS, etc.</td>
</tr>
</tbody>
</table>
Thank you

It’s not denial. I’m just selective about the reality I accept.