Selection of System at Planning Stage of Metro Rail Project

Presentation By:
Manoj Goyal, GM(System),

METRO- LINK EXPRESS FOR GANDHINAGAR AND AHMEDABAD (MEGA) CO. LTD.
## CORRIDOR DETAILS

### Route Details

<table>
<thead>
<tr>
<th>Name of Corridor</th>
<th>Distance (In Km)</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elevated</td>
<td>U/G</td>
<td>Total</td>
</tr>
<tr>
<td>East - West Corridor (Thaltej Gaam to Vastral Gaam)</td>
<td>14.402</td>
<td>6.335</td>
<td>20.737</td>
</tr>
<tr>
<td>North - South Corridor (APMC to Motera Stadium)</td>
<td>18.522</td>
<td>--</td>
<td>18.522</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>32.924</strong></td>
<td><strong>6.335</strong></td>
<td><strong>39.259</strong></td>
</tr>
</tbody>
</table>

### Station Details

<table>
<thead>
<tr>
<th>Name of Corridor</th>
<th>No. of Stations</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Elevated</td>
<td>U/G</td>
<td>Total</td>
</tr>
<tr>
<td>East - West Corridor (Thaltej Gaam to Vastral Gaam)</td>
<td>13</td>
<td>4</td>
<td>17</td>
</tr>
<tr>
<td>North-South Corridor (APMC to Motera Stadium)</td>
<td>15</td>
<td>--</td>
<td>15</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>28</strong></td>
<td><strong>4</strong></td>
<td><strong>32</strong></td>
</tr>
</tbody>
</table>
## PROJECT COST DETAILS

<table>
<thead>
<tr>
<th>Name of Corridor</th>
<th>Distance (In km)</th>
<th>Estimated completion cost with central taxes &amp; land cost (INR Crore)</th>
</tr>
</thead>
<tbody>
<tr>
<td>East - West Corridor (Thaltej Gam to Vastral Gam)</td>
<td>20.737</td>
<td>6681</td>
</tr>
<tr>
<td>North -South Corridor (APMC to Motera Stadium)</td>
<td>18.522</td>
<td>3994</td>
</tr>
<tr>
<td>Interest During Construction</td>
<td></td>
<td>98</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>39.259</strong></td>
<td><strong>10773</strong></td>
</tr>
</tbody>
</table>
## Financing of the Project

<table>
<thead>
<tr>
<th>Details</th>
<th>Amount (INR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equity of Govt. of India</td>
<td>1990 CR.</td>
</tr>
<tr>
<td>Equity of Govt. of Gujarat</td>
<td>1990 CR.</td>
</tr>
<tr>
<td>ODA/Loan (JICA)</td>
<td>6066 CR.</td>
</tr>
<tr>
<td>Sub-Ordinate Debt (SD) from GOG</td>
<td>727 CR.</td>
</tr>
</tbody>
</table>

**Total Project Cost - 10,773 CR.**
## SYSTEM SELECTION

The following systems are mainly available for Urban Mass Transit:

<table>
<thead>
<tr>
<th>System</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Capacity Metro System</strong></td>
<td>For high peak hour traffic densities exceeding 40,000 PHPDT</td>
</tr>
<tr>
<td><strong>Light Capacity Metro System</strong></td>
<td>For moderate peak hour traffic densities exceeding 8000 PHPDT.</td>
</tr>
<tr>
<td><strong>Light Rail Transit</strong></td>
<td>Modern trams-Street Cars running on Rails at grade or elevated with sharp curves of 24m radius.</td>
</tr>
<tr>
<td><strong>Other Systems</strong></td>
<td>• Maglev</td>
</tr>
<tr>
<td></td>
<td>• Linear Induction Motor (LIM) Train</td>
</tr>
<tr>
<td></td>
<td>• Monorail</td>
</tr>
<tr>
<td></td>
<td>• Bus Rapid Transit System</td>
</tr>
<tr>
<td></td>
<td>• Automated Guide way Transit System</td>
</tr>
</tbody>
</table>
In their report on urban Transport of 12th five year Plan, the working group has set the guidelines for the choice of different modes are as follows:

<table>
<thead>
<tr>
<th>System</th>
<th>PHPDT in 2021</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metro rail#</td>
<td>&gt;=15000 for at least 5km continuous length</td>
</tr>
<tr>
<td>LRT primarily at grade</td>
<td>&lt;= 10,000</td>
</tr>
<tr>
<td>Monorail@@</td>
<td>&lt;= 10,000</td>
</tr>
<tr>
<td>Bus Rapid Transit System</td>
<td>&gt;=4,000 and upto 20000</td>
</tr>
<tr>
<td>Organized City Bus Service as per urban bus specifications</td>
<td></td>
</tr>
</tbody>
</table>

- #for having Metrorail, the city should have a ridership of at least 1 million on organized public transport (any mode)
- @@Monorail is desirable only as a feeder system or where the narrow roads are flanked on either side by high rise buildings. In monorail while the cost of construction, operation and maintenance is almost the same as elevated metro rail, the carrying capacity is much lesser.
## PHPDT Demand Projection of MEGA

<table>
<thead>
<tr>
<th>Corridor/Year</th>
<th>PHPDT</th>
<th>PHPDT</th>
<th>PHPDT</th>
<th>PHPDT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2018</td>
<td>2021</td>
<td>2031</td>
<td>2043</td>
</tr>
<tr>
<td>North South Corridor</td>
<td>8476</td>
<td>12097</td>
<td>17778</td>
<td>26484</td>
</tr>
<tr>
<td>East West Corridor</td>
<td>10593</td>
<td>15659</td>
<td>19251</td>
<td>22944</td>
</tr>
</tbody>
</table>

MEGA has adopted a stable, tested and reliable Metro technology i.e. Light Capacity Metro System to cater PHPDT of 15000 to 25000.
MAJOR SYSTEMS OF METRO RAIL PROJECT

• ROLLING STOCK
• SIGNALLING
• TELECOMMUNICATION
• TRACTION POWER
• TRACK
ROLLING STOCK
ROLLING STOCK

• Level of automation in train operation
• Propulsion
• Bogies
• Communication
• TMS
• Car body
• Emergency evacuation system
• Fire protection system in Metro train
• Coupling Arrangement
<table>
<thead>
<tr>
<th>Grade of Automation</th>
<th>Type of train operation</th>
<th>Setting train in motion</th>
<th>Stopping train</th>
<th>Door closure</th>
<th>Operation in event of disruption</th>
</tr>
</thead>
<tbody>
<tr>
<td>GoA 1</td>
<td>ATP with driver</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
<td>Driver</td>
</tr>
<tr>
<td>GoA 2</td>
<td>ATP &amp; ATO with driver</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Driver</td>
<td>Driver</td>
</tr>
<tr>
<td>GoA 3</td>
<td>Driverless</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic Train attendant</td>
</tr>
<tr>
<td>GoA 4</td>
<td>UTO</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
<td>Automatic</td>
</tr>
</tbody>
</table>

ATP: Automatic Train Protection  
ATO: Automatic Train Operation  
GoA: Grade of Automation  
UTO: Unattended Train Operation
Level of automation in train operation

• Presently in India, GoA-2 is being followed.

• However we must aim for GoA-3 or GoA-4 level of automation in future projects.

• Criteria's to be ensured while adopting GoA 3/GoA 4:
  - Very high reliability requirements
  - Redundancy for key functions
  - Management of possible failure scenarios
  - Reliable communication links
  - Simple interface with commuters
  - Build-up commuter confidence with appropriate information
  - Robust obstruction detection device
Propulsion

- Brush less 3 phase induction motors
- Speed is regulated by VVVF control
- Regenerative braking by lowering the frequency and the voltage
- DC voltage from the 3rd Rail is stepped up through a ‘STEP up Chopper which feeds Inverter operated with PWM control technology and using IGBT.
- Percentage of Motorisation: 50% or 67% or 75%.
Bogies

• Bolster less lightweight fabricated /Cast steel bogies with rubber springs are now universally adopted in metro cars.
• Require less maintenance
• Overhaul interval is also of the order of 4,20,000km
• Use of air spring at secondary stage to keep floor level constant irrespective of passenger loading
Communication

- Two way communication between OCC and train driver.
- Cab to Cab communication.
- Emergency Intercom between Passenger & Train Driver.
- Chime when doors are closing and opening.
PASSENGER INFORMATION AND PASSENGER SALOON SURVEILLANCE SYSTEM

- Passenger Information System.
- Automatic Digital Voice Announcement and Public Address System.
- Broadcasting of Pre-recorded announcement through digital voice announcement system.
- LCD/TFT based Electronic Information Display (EID).
- Electronic Destination Display (EDD).

- Passenger saloon surveillance system based on IP Cameras, Network Video Recorder (NVR), CCTV.
Block Diagram of CCTV System
Train Management System (TMS)

TMS Features:

- TMS is a microprocessor based systems used for the automatic monitoring and display, control and fault reporting and recording of the subsystems on the train through the Train bus (ARCNET) and Local bus (RS-485).

- The main on-board devices are constantly monitored, and any failures are recorded and notify the driver in real time mode. This supports fast and accurate corrective measures to be taken when fault or emergency situations occur, and helps to promptly identify the cause of failure.
Car body

• Stainless steel / Aluminium car bodies.
• No corrosion repair.
• Energy saving due to its lightweight.
• Cost saving due to easy maintenance and reduction of repair cost.
• Riding comfort and safety in case of a crash or fire
Emergency Evacuation System

• Side Evacuation Vs. Front Evacuation
• Four doors on each side of the coach.
• Two emergency ramps per car with storage box under the saloon seat.

Locations of each emergency ramp
Fire Protection system

- Provided with fire retarding materials having
  - low fire load
  - low heat release rate
  - low smoke
- Low smoke zero halogen type cables used which ensures passenger safety in case of fire.
- One no. of Portable fire extinguisher in cab and two no. in each car.
- External Fire/smoke detector in cab HVAC.
Coupling Arrangement

- **Location:** Cab End
- **Automatic coupler with Pneumatic connection with or without Electric connection**
- **Energy absorption device**

- **3 car train**

![Diagram of Coupling Arrangement]

- **Semi-permanent Coupler**
- **3 car train**

- **Location:** Cab End
- **Semi-permanent Coupler with Pneumatic connection**
- **Energy absorption device**
Coupling Arrangement

Conversion to 6 car arrangement in future

Option-1

- Two 3 car trains can be coupled directly.

Option-2

- Special arrangement is required and can not be used separately.
SIGNALING AND TRAIN CONTROL SYSTEMS
Signaling and Train Control Systems

- Primary task: Safe and efficient movement of trains
- Reliable train detection – using Track circuits/Axle counter (DTG signaling) OR Radio Beacon (CBTC)
- Interlocking for Points/Signals control (wherever provided)
- ATP / ATO – Efficient and error free train operations
- ATS: Automation of operations, interfaces, sub-systems
<table>
<thead>
<tr>
<th></th>
<th>Sub-urban</th>
<th>Metros</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inter station</td>
<td>3 - 4 kms</td>
<td>1 km</td>
</tr>
<tr>
<td>Headway</td>
<td>4 – 10 minutes</td>
<td>2 -4 minutes</td>
</tr>
<tr>
<td>Dwell Time</td>
<td>30 – 60 seconds</td>
<td>20 – 40 seconds</td>
</tr>
<tr>
<td>Automation Requirement</td>
<td>Minimal</td>
<td>Intense</td>
</tr>
<tr>
<td>Interface</td>
<td>Few</td>
<td>Many</td>
</tr>
<tr>
<td>Block Working/ Safety</td>
<td>Manual ABS/ Auto/ ATP/ ATO</td>
<td>ATP/ATO/DTO/UTO/ Fixed Block/ Moving Block</td>
</tr>
</tbody>
</table>
DISTANCE TO GO SIGNALING – Currently being used in Indian Metros
CBTC SIGNALING – Definition

- CBTC as defined in IEEE 1474.1
  - Train location determination to a high precision, independent of track circuits.
  - Continuous, bi-directional RF communications between train and wayside, to permit the transfer of significantly more control and status data than is possible with conventional systems.
  - Vital train borne and wayside processors to provide continuous Automatic Train Protection (ATP)

✓ Various means of RF communication – Loops, wave guides, LCX, wi-fi radio
Communication Based Train Control (CBTC) systems based on moving block allows the reduction of the safety distance between two consecutive trains. This distance is varying according to the continuous updates of the train location and speed, maintaining the safety requirements. This results in a reduced headway between consecutive trains and an increased transport capacity.
Distance to Go to CBTC Moving Block

**DTG and CBTC Performances**

- **DISTANCE TO GO**
  - 40
- **Braking Curve for Distance to Go**
- **Stopping Point**
- **Authorized Speed**
  - Track Detection
- **CBTC MOVING BLOCK**
  - 40
- **Braking Curve in Moving Block**
- **Protection Envelop**
- **Limit of authority**
- **Gain in Moving Block**
  - [Radio Free Propagation]
Worldwide CBTC Installations
Why to have CBTC Signaling solution?

• Almost 99.99% availability means 10mts of downtime in a year.
• Maximised energy savings and optimised maintenance through accurate train simulation
• Reduced headways possible as compared to DTG.
• Matured technology now and Supports UTO operations (GoA4) – DTG technology slowly getting obsolete.
• Centralized ATS can control the entire lines, no local ATS.
• Backup can be provided using Interlockings and wayside signals for Crossing Stations
• Redundancy within the system:
  ✓ Interlocking and wayside systems
  ✓ Data communication systems
  ✓ On-board equipments
  ✓ CBTC radio links and systems
  ✓ ATS,
  ✓ BCC as backup to OCC
Why to have CBTC Signaling solution?

- Optimal driving performance for all train types
- Highest safety standards for all operating procedures
- Fast recovery of train operations after disruption due to equipment
- As more functions are managed by the central redundant servers:
  - Less Equipment are needed – even line-side signals can be dispensed with.
  - Less Power is required
  - Less Space is needed in the technical rooms
  - Less Maintenance
  - Less capital and life cycle Cost
- Scalable systems for future expansions
Signaling System Requirements - Planning

• Traffic requirements and forecast for future
• Headway requirements
• Grade of Automation required
• Availability of trained personnel for operations and maintenance
• Mean time between Failures (MTBF)
• Mean time to rectification (MTTR)
• Technology obsolescence
TELECOMMUNICATION SYSTEM
REQUIREMENTS OF TELECOM SYSTEMS IN METROS

- For Efficient O&M, essential to have an organized Telecom system network covering strategic locations – OCC, Stations, Depots etc. Also reliable links between train and OCC/Stations/Staff
- Telecom system provides necessary channels for voice/data/video signals for management and operations including security.
- Control and supervision of the sensitive AFC systems
- Data system requirement for Rolling stock interface to OCC/Depots
- Communication requirements for SCADA and Signaling/Track/Traction/Rolling Stock Fault controls
Telecom Infrastructure Features

• Proven solution on equivalent operational networks
• World Class level
• Standard-based and open architecture
• No Single Point of Failure
• Reliable, redundant, scalable and cost-effective
• Guaranteed and Secured infrastructure
• Easy to operate and maintain
• Integrated solution
TELECOM SUB SYSTEMS

- FIBER OPTIC BACKBONE SYSTEM
- USE OF IP BASED TECHNOLOGY IN PLACE OF OBSOLETE SDH SYSTEMS
- NETWORK MANAGEMENT SYSTEMS
- TETRA RADIO SYSTEM FOR TRAIN TO STATION/OCC COMMUNICATIONS
- TELEPHONE SYSTEMS
- PA SYSTEMS
- PIDS SYSTEMS
- CCTV SYSTEMS FOR SURVEILLANCE
- MASTER CLOCK AND STATION CLOCKS WORKING ON IP
- ACCESS CONTROL AND INTRUSION DETECTION SYSTEM
- CENTRALISED DIGITAL RECORDING SYSTEM
Telecommunication system - Solution Architecture
# Integrated Control Centre - Architecture Principle

## Integrated Control Security & Passenger Information Center

<table>
<thead>
<tr>
<th><strong>UNIFIED HUMAN MACHINE INTERFACE (HMI)</strong></th>
<th><strong>SERVERS</strong></th>
<th><strong>COMMUNICATIONS</strong></th>
<th><strong>SUBSYSTEM EQUIPMENT</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Map View</td>
<td>Traffic Control</td>
<td>PIS Manager</td>
<td>CCTV Manager</td>
</tr>
<tr>
<td>Traffic Supervision (ATS)</td>
<td>Security CCTV, PA / PIS</td>
<td>Auxiliaries SCADA</td>
<td>Power SCADA</td>
</tr>
<tr>
<td><strong>SUBSYSTEM</strong></td>
<td><strong>INTERFACES</strong></td>
<td><strong>COMMS</strong></td>
<td><strong>POWER</strong></td>
</tr>
<tr>
<td>Trackside</td>
<td>Interlocking</td>
<td>SCADA</td>
<td>Fire Detection</td>
</tr>
<tr>
<td>Train Control</td>
<td>Security CCTV</td>
<td>Electromechanical</td>
<td>Ventilation</td>
</tr>
<tr>
<td>Passenger Information (PIS)</td>
<td>Access Control</td>
<td></td>
<td>Fire Detection</td>
</tr>
</tbody>
</table>

### OPC Unified Architecture

- Trackside
- Interlocking
- Train Control
- Security CCTV
- Passenger Information
- Electromechanical
- Access Control
- Power
- Fire Detection
- Ventilation
- Fire Detection
TRACTION POWER SYSTEM
Traction Power System

• Selection of traction power system is based on economics of energy supplies, maintenance and capital cost. Different systems are used for urban and inter city areas.

• Electrification system can be classified by following main parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>750V DC, 1500V DC or 25kV AC</td>
</tr>
<tr>
<td>Traction Current</td>
<td>AC or DC</td>
</tr>
<tr>
<td>Current Collection system</td>
<td>Overhead or Third Rail</td>
</tr>
<tr>
<td>Control</td>
<td>Local or Remote</td>
</tr>
</tbody>
</table>
Direct Current system

• Large speed range can be achieved by VVVF control.

• Generally operates on a voltage below 1 KV for safety reason.

• Relatively low DC voltage that the motors can use directly.

• To minimize resistive losses, it requires:
  – thick & short supply cables/wires
  – closely spaced converter stations.

• Limit over distance between feeder stations
Third Rail Current Collection

- More compact.
- Better to be used for smaller-diameter tunnels.
- Prone to losses due to limit of voltage upto 1200 V.
- The use of AC is not feasible for third rail.
- Third rail systems can be designed to use top contact, side contact or bottom contact.
- Limited to relatively low voltages, limiting the size and speed of trains.
- Less Visual Pollution as compared to OCS.
Overhead Current Collection

- Uses higher voltages for efficiency consideration.
- Smaller energy loss.
- Economical system.
- Drawbacks:
  - Phases loaded unequally
  - Significant EMI generated
- Special structure needs to be constructed for overhead line.
- Special provision to be made where there is a overhead cross-over in urban areas and for tunnel entry.
OVERHEAD CURRENT COLLECTION
THIRD RAIL CURRENT COLLECTION

© 2011 Peter Ehrlich
THIRD RAIL CURRENT COLLECTION
Regen Energy Recovery System (for DC third rail systems)

- To feed back the regenerative brake energy back to supply system.
- An advanced substation for networks from 600V DC to 1500V DC
- Best energy efficiency with 99% of braking energy recovery & high energy quality
- Reduced infrastructure

![Diagram showing comparison between classic and HESOP substations.](image-url)
MEGA’s Choice for Traction Power System

• MEGA has considered 750 V DC third rail system for the project due to the following reasons.
  – No visual intrusion in City Skyline.
  – OHE is more failure prone due to Kite flying in Ahmedabad.
  – No electromagnetic interference.
  – Less clearance is required in tunnels and passing under bridges.
  – To overcome the possibility of electrocution to daily commuters, MEGA is proposing PSDs in station areas.
TRACK SYSTEM

• TYPES OF TRACK SYSTEM
  – BALLASTED
  – BALLASTLESS
BENEFIT OF BALLASTLESS TRACK OVER CONVENTIONAL BALLASTED TRACK

- REDUCTION OF STRUCTURE HEIGHT
- HIGHER AVAILABILITY FOR OPERATION
- HIGH LATERAL TRACK RESISTANCE
- LESS MAINTENANCE
- GOOD SUPPORT AND LONG SERVICE LIFE
- VIBRATION ATTENUATION (IN TUNNEL ONLY)
- LOW DEAD LOAD (VIADUCT ONLY)
- EASE OF CONSTRUCTION
BENEFIT OF CONVENTIONAL BALLASTED TRACK OVER BALLASTLESS TRACK

- RELATIVELY LOW CONSTRUCTION COST
- HIGH ELASTICITY
- HIGH MAINTAINABILITY AT RELATIVELY LOW COST
- HIGH NOISE ABSORPTION
- EASE OF CONSTRUCTION
Track System Choice

- MEGA has adopted ballastless track on viaducts & tunnels.

- However, in depot yard area, ballasted track will be adopted.
Base-plated Ballastless track in tunnel
Thank You