3. SYSTEM DESIGN

3.1 INTRODUCTION

Metro rail technology offers the advantage of latest technology being available off the shelf with standardization and indigenization. This technology has already stabilized for reliability, acceptance and availability of manufacturing infrastructure (for spare parts etc.) around the world and in India. Metro rail system has already been implemented in various Indian cities viz. Delhi, Kolkata, Mumbai, Bangalore, Jaipur etc. and being implemented/proposed for many other cities viz. Chennai, Hyderabad, Kochi, Lucknow, Nagpur etc.

The urban transport requirements of Varanasi City have been evaluated based on projected traffic demand. Considering the city specific characteristics, traffic demand, availability of right of way, Medium Capacity Metro rail system, which can cater to design capacity of 27000 PHPDT, is proposed to be adopted for Varanasi Metro corridors.

3.2 PERMANENT WAY

3.2.1 Gauge

The options available for P-way Gauge selection are – Broad Gauge (1676mm), Standard Gauge (1435mm), Meter Gauge (1000mm). The relative merits & demerits of these gauges are discussed below:

- **Meter Gauge (MG)**

  Though, Meter Gauge (1000mm) has been used at few locations for conventional railway networks but now it is being converted into Broad Gauge due to its techno-economical consideration and uniformity of track gauge.

  Internationally, Meter gauge is not a common gauge for Metro applications and it will support lesser coach width and lesser carrying capacity. Moreover, benefits of standardization and economy of scale are not available with Meter Gauge systems.

- **Broad Gauge (BG)**

  Broad Gauge (1676mm) is most widely used rail gauge on Indian Railways with availability of proven indigenous technology and expertise of Indian Railways system. However, conventional railway systems and Metro systems cater for different form of transport demands (Long/medium distance inter-city vs. intra-city demands) and involve different
types of coaching systems. Train control systems of most of the conventional railway systems are different than the systems being used for Metro networks. Hence track integration of conventional railway system and metro system is not required.

In case, stand alone Metro network (not interlinked with adjoining conventional B.G rail network) is considered on Broad Gauge, it will support higher passenger carrying capacity as upto 3.66 m wide coaches may be operated as compared to 3.2 m coach width for Standard Gauge. However, Broad Gauge coaches are not the standard product of reputed Rolling stock manufacturers and require additional procurement time and cost.

Moreover, Broad Gauge will require larger track center and smoother curves which may not be possible in urban scenario. Broad Gauge will also involve higher cost on account of wider civil infrastructure and more land/ property acquisition.

- **Standard Gauge (SG)**

Standard Gauge (1435mm) is being used worldwide for Metro Railways with modern state of the art technology. Standard Gauge permits sharper curves (120m), which is advantageous for metro alignment in urban scenario having sharp bends. It also results in minimized property demolition and property acquisition. The Land requirement for the maintenance depots, where a large number of lines are connected together, is also lower in Standard Gauge.

The width of the civil infrastructure required for SG is less as compared to BG due to lesser track centre and coach width. In Standard Gauge 1 in 7 and 1 in 9 turn-outs, which occupy lesser length, are generally used compared to 1 in 8 ½ and 1 in 12 turn-outs used in Broad Gauge. Length of cross-over for Standard Gauge is lesser than for Broad Gauge. This not only helps in maintaining higher speed over longer length approaching terminal/ interchange stations but also reduces land requirement for depots where a large number of lines are connected together. The exit/ entry to depot too is efficient.

Standard Gauge rolling stock results in recurring saving in energy consumption during operation as for the same passenger carrying capacity, gross weight of a metro coach is lower for Standard Gauge than for Broad Gauge.

### 3.2.2 Recommendation

The MRTS alignment will pass through built-up areas or stretches and in view of the advantages offered by Standard Gauge as brought out above, it is proposed to adopt Standard Gauge (1435mm) for Varanasi MRTS corridor.
3.3 TRACK STRUCTURE

3.3.1 General

Track on Metro Systems is required to cater peculiar requirements as under:-

- Highest standards for safety of passengers and property.
- High reliability to minimize failures as Low as Possible.
- Low Axle loads of approx. 16MT and low GMT.
- Very High Frequency of train operations on alignment having sharp curves and gradients.
- Frequent braking and acceleration at stations typically located @ 1 Km distance.
- Minimum noise and vibrations.
- Maximum comfort to passengers.

Above working scenario leads to requirement of very high degree of safety and reliability but with very small window for inspections, maintenance and renewal of track assets. In view of above, the track structure selected for Metro system should have long life and high degree of reliability to reduce the maintenance and renewal efforts.

3.3.2 Rail Section and Grade

In view of sharp curves, steep gradients, frequent braking, requirement of less noise & vibration, rails on main lines should have high degree of wear resistance. To reduce maintenance and renewal efforts, Head Hardened (HH) rails of grade 1080 are proposed for main lines. Presently, HH rails are not manufactured in India and with regard to imported rails, two broad choices are available with regard to rail section i.e. 54 KG UIC and 60 Kg UIC section. Though the axle load and GMT of Metro rolling stocks are less and on criteria of axle load alone, 54 Kg UIC section shall be sufficient but keeping in view the difficulties in inspection, maintenance and renewal of rails, 60 KG UIC section is recommended, which will also have longer life than 54 Kg rail section. It is understood that SAIL, Bhilai is developing facilities for 60 KG HH rails for Indian Railways and it is expected that in near future, indigenous 60 KG 1080 HH rails shall be available.

Thus for main lines, 60KG UIC HH rails of grade 1080 are proposed. For other than main lines and Depot lines, 60 kg rails of grade 880 (without Head hardening) are proposed. These rails are being manufactured indigenously. The rails for main lines and depot lines should also conform to the technical specifications laid down by Indian Railways in IRS-T-12-2009.
The rails should have cant of 1 in 20 and wheel profile of rolling stock should be compatible with rail profile.

3.3.3 Formation (Ballastless and Ballasted)

In views of peculiar working scenario outlined in preceding paras, ballastless track is proposed for elevated and underground stretches. Error! Reference source not found. shows the plinth type ballastless track structure on viaducts.

At Depot, following track structure is proposed to serve specific usage:-

- Ballastless for Washing Line
- Steel pedestal for inspection lines
- Embedded Rail type inside Workshop
- Conventional Ballasted track for Stabling and other line

3.3.4 Fastening System for Ballasted Track

In Feb. 2015, Govt. of India, Ministry of Railways- Nodal Ministry entrusted with technical planning of Metro Systems, has issued “Procedure for Safety certification and Technical clearance of Metro System”. Part-A, Annexure C-2 of the said document covers “Performance criteria of fastening system for ballastless track on Metro Railways/ MRTS System”. Ministry of Railways has already approved certain fastening systems complying the requisite performance criteria.

Further, scope for introduction of “new fastening system” has been made available (for those not approved by Ministry of Railways) with the proviso that the details of such fastening systems shall be made available to MoR and the same will be kept under observation by MoR for a period of two years under service conditions in association with Metro Railways/ MRTS system.

3.3.5 Turnouts and Scissor Crossover

From considerations of maintainability and riding comfort, it is proposed to lay following two types of turnouts:

- On main lines, 1 in 9 type turnout with a lead radius of 300 m and speed potential on divergent track as 45 km/h FIGURE 3.2.
• However, at Benia Bagh station, due to space constraint, 1:7 crossovers have been proposed with lead radius of 140m and speed potential on divergent track as 25km/h.

• On Depot lines, 1 in 7 type turnout with a lead radius of 140 m and speed potential on divergent track as 25 km/h FIGURE 3.3.

• The Scissors cross-overs on Main Lines (1 in 9 type) will be with a minimum track centre of 4.5 m FIGURE 3.4.

3.3.6 Welding

To minimize noise and vibrations, track joints should be welded by Flash Butt Welding Technique and Alumino-Thermit Welding may be done only for those joints which cannot be welded by Flash Butt Welding Technique.
FIGURE 3.1: TYPICAL CROSS SECTION OF BALLASTLESS TRACK ON VIADUCT

NOTE:-
ALL DIMENSIONS ARE IN mm UNLESS OTHERWISE NOTED.
MINIMUM DEPTH OF PLINTH = 175 mm.
FIGURE 3.2: 1 IN 9 TYPE TURN-OUT

R = 300m
FIGURE 3.3: 1 IN 7 TYPE TURN-OUT
FIGURE 3.4: SCISSOR CROSS-OVER (1 IN 9 TYPE)
3.4 **Traction System**

The power supply system is required for operation of MRTS for running of trains, station services including illumination of buildings, lifts, escalators, signalling, telecommunication, firefighting etc., workshops, depots & other maintenance infrastructure within the premises of metro system.

Traditionally, electric traction has been used to meet the requirement of high acceleration, pollution free services and to achieve the optimum performance in urban, Sub-urban and main line rail transport system. Selection of an appropriate technology for traction system may be based on following factors:

- Cost of the technology
- Previous experience & proven-ness
- Maintenance requirements
- Energy Efficiency
- Aesthetics, Economic viability & Sustainability

The Cost of traction power system depends upon the following factors:

- Maximum power demand of load
- Level of redundancy & reliability
- Land Cost particularly for Traction Sub-station and Sectioning Posts
- Availability of technology and equipment at Competitive price

There are three standard and proven systems of electric traction for use in suburban and metro lines:

- 750 V DC Third Rail System
- 1500 V DC Third Rail/ Overhead Catenary System
- 25 KV AC system

The merits and de-merits of these systems are discussed below:

1. **750 V DC third rail system**

750 V DC third rail systems is the most primitive traction system which has been extensively used in metros and more than 60% of existing metro systems in the world utilize 600-750V DC third rail system. However, the traffic handling capacity of this system is limited to 45,000 PHPDT.
Kolkata and Bangalore Metro have 750V DC traction system introduced in 1984 and 2011 respectively. Kolkata Metro was built with the primitive technologies i.e. use of Steel third rail with top contact, non-air conditioned rakes with tunnel air conditioning and non-regeneration. Bangalore Metro is using the advanced technology with Al composite third rail; air conditioned coaches and VVVF control of traction motor with regenerative braking.

750 V DC third rail systems offer the best aesthetic solution because of the absence of any overhead conductors and supporting structures. The 750V dc third rail needs very little maintenance since by virtue of its solid rigid design it is able to withstand passing of current collector devices of the train without any significant wear & tear. However maintenance of substation costs more as they are more in numbers.

Because of lower voltage, the 750V DC traction power system handles much higher operating current resulting into higher voltage drop and line losses along the third rail distribution system. This necessitates closer spacing of sub-stations, leading to higher cost of construction. The presence of live third rail at ground may be hazardous to safety of commuters and maintenance personnel if they fail to adopt safety precautions.

In a third rail system, where the running rails are used as a return path, a part of the stray current leaks into the track structure. This current is called Stray current. The stray current corrosion is often encountered in dc-electrified systems and therefore, suitable measures are required for protection against corrosion of metallic components in the track-structures as well as metallic reinforcement and metal pipes etc in the vicinity of metro alignment.

ii. **1500 V DC Third Rail/ Overhead Catenary System**

1500V DC Third Rail/ Overhead Catenary System have been adopted by few metros to overcome the limitation imposed by 750V DC system for catering to traffic of 60,000-80,000 PHPDT.

The 1500V DC third rail system has been adopted in Chinese Metros by Guangzhou Metro and Shenzhen Metro during last decade from aesthetics and reliability considerations. It has constraints on requirement of power block for any kind of attention to track, signalling, other equipment and side evacuation. The 1500 V DC third Rail system can meet higher traffic needs with 5.4m tunnel diameter. The voltage drop and line losses are lesser than the 750V DC system but much higher than the 25kV ac traction system.
The 1500V DC Overhead Catenary System requires use of catenary masts on elevated viaducts thereby affecting aesthetics of the city. Overhead catenary may be prone to lightning and thunderstorm. In addition, suitable measures are required to manage the stray currents which may cause corrosion of metallic structures. Mumbai suburban section of Western Railway and Central Railway which was provided with 1500 V DC catenary is now being converted to 25 kV ac systems due to limitation of this system to handle increase in the traffic demand.

iii. **25 KV AC system**

25 KV AC traction systems have been adopted by Delhi, Jaipur, Chennai and Hyderabad metro rail corporations as well as Indian Railways. The system has the potential to carry large traffic (60,000-100,000) PHPDT and possibility of linking to mainline railways, if required.

In comparison to DC systems, the regeneration capacity for 25 KV AC system is more and the line losses are less. In case of 25KV AC traction, 100% recovery of regenerated energy is possible compared to 60% in case of 750 V DC if no special measures are taken to recover the regenerated energy. Energy saving on account of regenerative breaking is about 25-35% of traction energy in case of 25kV ac traction as compared to about 20% in case of 750V dc traction. This makes the 25kV ac traction system more energy efficient.

Suitable measures are required for mitigation of electro-magnetic interference (EMI) caused by single-phase 25kV AC traction currents. 25kV AC train will require the heavy transformers to be carried in the motor coach which will increase the weight and hence there will be an increase in the energy consumption.

Unlike DC traction this system does not require substations at frequent intervals due to high voltage, reduced current levels and lower voltage drops as a result, there is substantial reduction in costs. Overall cost of land and equipment’s for 25kV ac traction system is significantly lower compared to that for 1500V dc or 750V dc traction system. In addition, it is widely used traction system on Indian Railways with availability of proven indigenous technology for all the components of 25 kV ac systems.

**Merits and Demerits of 750V dc third rail traction system**

The selection of proper traction system has a great impact on capital cost, operational cost, traffic growth, operational flexibility and expandability of the system in future. It is also linked to the ultimate capacity being planned. Appropriate selection of traction system at design stage is essential to achieve optimum performance of a MRTS system. The merits of 750V dc third rail traction system over 1500V DC OHE or 25kV ac OHE traction system are discussed in brief as below:
Aesthetics: In the absence of any overhead conductors and supporting structures, the 750V DC Third Rail System offers the best aesthetic solution, compared to the Overhead Catenary System. Since Varanasi City is a popular pilgrimage point for Hindus and attracts large number of tourists, the aesthetics of the city should be taken care.

Lower Tunnelling Costs: Since there is no requirement of maintaining overhead clearances, third rail system can be accommodated in a lower tunnel diameter than the tunnel diameter required for overhead catenary systems, leading to reduced cost of tunnelling.

Experience in Installation and O&M: This system is oldest and extensively used in various World Metros and thus is time tested due to availability of considerable experience in installation and O&M.

Low wear and Tear: Due to its solid rigid design it is able to withstand passing of current collector devices of the trains without any significant wear and tear. The effect of wind and rain on the third rail is minimum and on account of the low height. Thus, little maintenance is required for the third rail. However maintenance of substation costs more as they are more in number.

Low Tare Weight: 750V dc Third Rail System like ac traction system do not require provision of transformers and front end converters, the train cost becomes less for 750V dc systems compared to 25 kV ac traction. The weight of train decreases by 5% on this account which also decreases energy consumption.

Other Benefits: Suitable measures are required for mitigation of EMC/EMI caused by single phase 25 kV AC traction systems; whereas no such arrangement is required in case of 750V DC Third Rail System. 25 kV OCS system can be prone to thunderstorms, lightning and intrusion by birds and animals if appropriate measures are not taken. Whereas, 750V DC Third Rail System is not accessible to such situations.

750V DC system has certain demerits which are given below:

Traffic Handling Capacity: The traffic handling capacity of 750V DC Third Rail system is limited to 45,000 PHPDT. However, the estimated PHPDT for the ultimate design year is 24000 passengers for BHU to BHEL corridor and 18000 passengers for Beniabagh to Sarnath corridor. Hence, the system is capable of handling the traffic for Varanasi Metro corridors.

Stray Current: In DC systems, the stray currents cause the corrosion of the metallic structures. However, these stray currents can be suppressed by adopting proper mitigation measures.
In view of above merits and considering the ultimate traffic demand i.e. 24000 and 18000 PHPDT for BHU to BHEL corridor and Benia Bagh to Sarnath Corridor respectively, Either 1500 V DC or 750V DC Third Rail System may be adopted for Varanasi Metro corridors. Due to very few metro systems worldwide and lack of technical details of 1500 V DC third rail traction system, 750 V DC third rail traction systems is proposed at this stage.

3.5 Rolling Stock

Following important criteria is proposed for selection of rolling stock:

- Passenger comfort & safety
- Proven equipment with high reliability
- Energy efficiency
- Light weight equipment and coach body
- High rate of acceleration and deceleration
- Optimized scheduled speed
- Flexibility to meet increase in traffic demand
- Aesthetically pleasing Interior and Exterior
- Low Life cycle cost

3.5.1 Selection of Technology

The low life cycle cost is achieved by the way of reduced scheduled and unscheduled maintenance and high reliability of the sub-systems. It is possible to achieve these objectives by adopting state of the art proven technologies. The selection of following technologies is proposed to ensure low life cycle cost.

(i) Car body

In the past carbon high tensile steel was invariably used for car bodies. In-fact almost all the coaches built by Indian Railways are of this type. These steel bodied coaches need frequent painting and corrosion repairs which may have to be carried out up
to 4-5 times during the service life of these coaches. It is now standard practice to adopt stainless steel or aluminium car bodies.

(ii) Bogies

Bogies less light weight bogies with rubber springs are now universally adopted in metro cars. These bogies require less maintenance and overhaul interval is also of the order of 4,20,000 km. The use of air spring at secondary stage may be considered with a view to keep the floor levels of the car constant irrespective of passenger loading unlike those with coil spring. A smooth curving performance with better ride index will be ensured by provision of above type of bogies.

(iii) Braking System

The brake system shall consist of –

4. An electro-pneumatic (EP) service friction brake
5. A fail safe, pneumatic friction emergency brake
6. A spring applied air-release parking brake
7. An electric regenerative service brake

Provision of smooth and continuous blending of EP and regenerative braking

The regenerative braking will be the main brake power of the train and will regain the maximum possible energy and pump it back to the system and thus fully utilize the advantage of 3 phase technology. The regenerative braking should have air supplement control to bear the load of trailer car.

(iv) Propulsion System Technology

In the field of Electric Rolling Stock, DC series traction motors have been widely used due to its ideal characteristics and good controllability for traction applications. But these traction motors required intensive maintenance because of commutators and electro-mechanical contractors, resistors etc.

The brush less 3 phase induction motors has now replaced the D.C. series motors in traction applications. The induction motor, for the same power output, is smaller and lighter in weight and ideally suited for rail based Mass Rapid Transit applications. The motor tractive effort and speed is regulated by 'Variable Voltage and Variable frequency' control and can be programmed to suit the track profile and operating requirements. Another advantage of 3 phase A.C. drive and VVVF control is that regenerative braking
can be introduced by lowering the frequency and the voltage to reverse the power flow and to allow braking to very low speed.

For Varanasi Mass Rapid Transit System, three phase AC traction drive with VVVF control is recommended for adoption.

(v) Interior and Gang Ways

The passenger capacity of a car is maximized in a Metro System by providing longitudinal seats for seating and utilizing the remaining space for standing passenger. Therefore all the equipments are mounted on the under frame for maximum space utilization. The gangways are designed to give a wider comfortable standing space during peak hours along with easy and faster passenger movement especially in case of emergency.

(vi) Passenger Doors

For swift evacuation of the passenger in short dwell period, four doors of adequate width, on each side of the coach may be considered. These doors shall be of such dimensions and location that all the passengers inside the train are able to evacuate within least possible time without conflicting movement. Automatic door closing mechanism is envisaged from consideration of passenger safety.

(vii) Air Conditioning

With passenger loading of 6 persons /m2 for standee area and doors being closed from consideration of safety and with windows being sealed type to avoid transmission of noise, the air conditioning of coaches is considered essential. Each coach shall be provided with two air conditioning units capable of automatically controlling interior temperature throughout the passenger area at all times under varying ambient condition up to full load. For emergency situations such as power failure or both AC failures etc. ventilation provision supplied from battery may be made.
(viii) Cab Layout

The modern stylish driver panel shall be FRP moulded which give maximum comfort and easy accessibility of different monitoring equipments to the driver along with clear visibility. The driver seat may be provided at the left side of the cabin.

3.5.2 Broad Features of Rolling Stock

Rolling Stock proposed for the Varanasi MRTS corridors will be similar to Bangalore/ Kochi Metro. The specifications of the rolling stock and its procurement may be decided on the basis of the project implementation mechanism. The broad features of Rolling Stock which may be followed are indicated in TABLE 3.1.

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Parameter</th>
<th>Rolling Stock</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Basic Unit</td>
<td>3 Car basic units 2MC and 1 TC.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Every coach should be fully interchangeable with any other coach of same type.</td>
</tr>
<tr>
<td>2</td>
<td>Train Composition</td>
<td>3- Car: DMC+TC+DMC</td>
</tr>
<tr>
<td>3</td>
<td>Coach construction</td>
<td>Light weight stainless steel/Aluminium body</td>
</tr>
<tr>
<td>4</td>
<td>Axle load</td>
<td>≤16 T</td>
</tr>
<tr>
<td>5</td>
<td>Braking System</td>
<td>Regenerative Braking</td>
</tr>
<tr>
<td>6</td>
<td>Propulsion system</td>
<td>3 phase drive system with VVVF control</td>
</tr>
<tr>
<td>7</td>
<td>Type of traction supply</td>
<td>750 V DC Third Rail system</td>
</tr>
</tbody>
</table>

3.5.3 Coach Dimensions

The following dimensions of the coach are proposed for Varanasi Metro (TABLE 3.2).

<table>
<thead>
<tr>
<th>Type of coach</th>
<th>Length*</th>
<th>Width</th>
<th>Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driving Motor Car (DMC)</td>
<td>21.64 m</td>
<td>2.9 m</td>
<td>3.9 m</td>
</tr>
<tr>
<td>Trailer car (TC)/Motor Car (MC)</td>
<td>21.34 m</td>
<td>2.9 m</td>
<td>3.9 m</td>
</tr>
</tbody>
</table>

*Maximum length of coach over couplers/buffers = 22.6 m
3.5.4 Passenger Carrying Capacity

In order to maximize the passenger carrying capacity, longitudinal seating arrangement shall be adopted. The whole train shall be vestibule to distribute the passenger evenly in all the coaches. Criteria for the calculation of standing passengers are 3 persons per square meter of standing floor area in normal state, 6 persons in crush state of peak hour and 8 persons in dense crush state of peak hour.

The train composition is proposed as 3 - Car Train (DMC+TC+DMC). The carrying capacity of Metro Rail Vehicle is indicated in TABLE 3.3 below:

TABLE 3.3: CARRYING CAPACITY OF METRO RAIL

<table>
<thead>
<tr>
<th>Description</th>
<th>Driving Motor Car (DMC)</th>
<th>Trailer Car (TC)</th>
<th>3 Car Train</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Normal</td>
<td>Crush</td>
<td>Dense Crush</td>
</tr>
<tr>
<td>Seated</td>
<td>43</td>
<td>43</td>
<td>43</td>
</tr>
<tr>
<td>Standing</td>
<td>102</td>
<td>204</td>
<td>272</td>
</tr>
<tr>
<td>Total</td>
<td>145</td>
<td>247</td>
<td>315</td>
</tr>
</tbody>
</table>

Normal - 3 Per/sqm of standee area, Crush- 6 Per/Sqm of standee area, Dense Crush – 8 Per/Sqm of standee area.

3.5.5 Weight

The weights of motor cars and trailers are estimated in TABLE 3.4, considering the average passenger weight as 65 kg.

TABLE 3.4: WEIGHT OF MASS RAIL VEHICLES (TONS)

<table>
<thead>
<tr>
<th>Description</th>
<th>DMC</th>
<th>TC</th>
<th>3 Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>TARE WEIGHT (Max.)</td>
<td>40</td>
<td>40</td>
<td>120</td>
</tr>
<tr>
<td>Passenger</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Normal@3p/m²)</td>
<td>9.43</td>
<td>10.40</td>
<td>30.23</td>
</tr>
<tr>
<td>(Crush@6p/m²)</td>
<td>16.12</td>
<td>17.55</td>
<td>51.22</td>
</tr>
<tr>
<td>(Crush@8p/m²)</td>
<td>20.54</td>
<td>22.30</td>
<td>65.13</td>
</tr>
<tr>
<td>Gross</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Normal@3p/m²)</td>
<td>49.43</td>
<td>50.40</td>
<td>150.23</td>
</tr>
</tbody>
</table>
### 3.5.6 Performance Parameters

To achieve the desired schedule speed and running time between stations, the following values of acceleration and deceleration are recommended in consideration of riding comfort, adhesion and requirement of makeup time.

- Max. Design speed : 90 kmph
- Max. Acceleration : 1.0 m/s²
- Max. Deceleration : 1.1 m/s² (Normal brake); More than 1.3 m/s² (Emergency brake)

**FIGURE 3.5: SIMPLIFIED VELOCITY – TIME OPERATION CURVE**

<table>
<thead>
<tr>
<th>Description</th>
<th>DMC</th>
<th>TC</th>
<th>3 Car</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Crush@6p/m²)</td>
<td>56.12</td>
<td>57.55</td>
<td>171.22</td>
</tr>
<tr>
<td>(Crush@8p/m²)</td>
<td>60.54</td>
<td>62.30</td>
<td>185.13</td>
</tr>
<tr>
<td>Axle Load @6p/m²</td>
<td>14.03</td>
<td>14.39</td>
<td></td>
</tr>
<tr>
<td>Axle Load @8p/m²</td>
<td>15.14</td>
<td>15.57</td>
<td></td>
</tr>
</tbody>
</table>

The axle load @ 6persons/m² of standees works out in the range of 14.03T to 14.39T per coach. Heavy rush of passengers with loading @ 8 standees per sq. meter can be experienced occasionally during peak hours. It is recommended to design the coaches with sufficient strength so that even with this overload, the design will not result in over stresses in the coach. Coach and bogie should therefore be designed for 16 T axle load.
3.6 VENTILATION AND AIR-CONDITIONING SYSTEM

The details of the Ventilation and Air-conditioning (VAC) system requirements for the underground sections of the proposed corridors of Varanasi Metro include the following:

- Station Air-conditioning System
- Ventilation System for station plant rooms (ancillary spaces)
- Station Smoke Management System
- Tunnel Ventilation System

3.6.1 Need for Ventilation and Air Conditioning

The underground stations of the Corridor are generally built in a confined space. A large number of passengers occupy concourse halls and the platforms, especially at the peak hours. The platform and concourse areas have a limited access from outside and do not have natural ventilation. It is therefore, essential to provide forced ventilation in the stations and inside the tunnel for the purpose of:

- Supplying fresh air for the physiological needs of passengers and the authority’s staff;
- Removing body heat, obnoxious odours and harmful gases like carbon dioxide exhaled during breathing;
- Preventing concentration of moisture generated by body sweat and seepage of water in the sub-way;
- Removing large quantity of heat dissipated by the train equipment like traction motors, braking units, compressors mounted below the under-frame, lights and fans inside the coaches, A/c units etc.
- Removing vapour and fumes from the battery and heat emitted by light fittings, water coolers, Escalators, Fare Gates, etc. working in the stations;
- Removing heat from air conditioning plant and sub-station and other equipment, if provided inside the underground station.

This large quantity of heat generated in underground stations cannot be extracted by simple ventilation, especially when the outdoor air temperature and humidity is high. It is, therefore, essential to provide mechanical cooling in order to remove the heat to the
maximum possible extent. As the passengers stay in the stations only for short periods, a fair degree of comfort conditions, just short of discomfort are considered appropriate.

3.6.2 Sub Soil Temperature

The temperature conditions of sub-soil play a vital role in the system design of the underground stations. It is also expected that water table surrounding the underground alignment is not very much below the surface level, thereby facilitating adequate heat exchange between the tunnel structures and soil.

3.6.3 Internal Design Conditions in Underground Stations

It is essential to maintain appropriate conditions in the underground stations in order to provide a comfortable and pollution-free environment. The plant capacity and design of VAC system needs to be optimized for the designed inside conditions.

The Indian Standards & Codes, which pertain to office-buildings, commercial centres and other public utility buildings, have no guidelines on temperature standards to be maintained for the underground mass rapid transit systems as yet. The standards used for buildings cannot be applied straightaway for the underground spaces, because the patrons will stay for much shorter durations in these underground stations.

The comfort of a person depends on rapidity of dissipation of his body heat, which in turn depends on temperature, humidity and motion of air in contact with the body. Body heat gets dissipated by the process of evaporation, convection and conduction. Evaporation prevails at high temperature. Greater proportion of heat is dissipated by evaporation from the skin, which gets promoted by low humidity of air. The movement of air determines the rate of dissipation of body heat in the form of sensible and latent heat.

There are different comfort indices recognized for this purpose. The ‘Effective Temperature’ criterion was used in selecting the comfort conditions in the metro systems. In this criterion, comfort is defined as the function of temperature and the air velocity experienced by a person. More recently a new index named RWI (Relative Warmth Index) has been adopted for metro designs worldwide. This index depends upon the transient conditions of the metabolic rate and is evaluated based on the changes to the surrounding ambience of a person in a short period of about 6 to 8 minutes. It is assumed that during this period human body adjusts its metabolic activities. Therefore in a subway system where the train headway is expected to be six minutes or less, RWI is the preferred criterion.
3.6.4 Design Parameters for VAC System

Varanasi has a humid subtropical climate with extremely hot summers from late March to early June, the monsoon season from late June to late September and chilly winter nights and foggy or sunny days from November to February.

Based on prevalent practices and ambient conditions of Varanasi, the following VAC system design parameters are assumed to be provided for underground sections of the proposed corridors of Varanasi Metro:

(i) Outside ambient conditions:
   Summer: - 42.1°C (DB), 23°C (WB)
   Monsoon: - 29°C (DB), 33°C (WB)

(ii) Inside design conditions:
   Platform areas - 27°C at 55% RH
   Concourse - 28°C at 60% RH

(iii) Tunnel design conditions:
   Normal conditions - Max. DB 40°C
   Congested conditions - Max. DB 45°C

(iv) Minimum fresh air - 10% or 18 cmh/ person
    (in station public area)

3.6.5 Design Concepts for VAC System

There are various VAC design concepts technically feasible in a subway system that can provide and maintain acceptable subway environment conditions under different requirement and constraints. These are: Open type; Closed type; Mid - Tunnel Cooling; Semi Transverse Ventilation; Use of jet fans; use of mid-shafts; platform screen doors etc. The experience available from the design of VAC system for Delhi Metro also provides key guidelines.

From the experience of DMRC, for such conditions it can be concluded that with open shaft system the piston effects can be sufficient to maintain acceptable conditions inside the tunnel, as long as the ambient DB temperature is below 330°C. When the outside temperature is higher than 330°C, the tunnel shafts should be closed to prevent any further exchange of air with atmosphere. The station premises (public areas) can be equipped with separate air-conditioning system during the summer and monsoon months to provide acceptable environment for patrons. There shall be provision of Trackway...
3.6.6 Track Way Exhaust System (TES)

The TES is to be installed in the train ways of each station to directly capture heat rejected by the vehicle propulsion, braking, auxiliary and air conditioning systems as the train dwells in the station. The TES includes both an under platform exhaust (UPE) duct and an Over-trackway (OTE) exhaust duct. The TES uses ducts formed in the under platform void and over the trackway. Exhaust intakes are to be located to coincide...
with the train-borne heat sources.

3.6.7 Tunnel Ventilation System (TVS)

The TVS is provided in a Subway system essentially to carry out the following functions:

a) Train Pressure relief during normal operation

b) Ventilation during maintenance periods, if required

c) Removal of smoke during emergency conditions

d) Maintenance of smoke free evacuation route and provision of adequate fresh air during fire related emergencies.

There are various operating modes (scenarios) for the Tunnel Ventilation system. These are described as under:

• Normal Conditions

Normal condition is when the trains are operating to timetable throughout the system, at prescribed headways and dwell times, within given tolerances. The primary source of ventilation during normal conditions is generated by the movement of trains operating within the system and, in some cases, the trackway exhaust system.

During summer and the monsoon seasons, the system will be functioning essentially with the station air conditioning operating. The vent shafts to the surface will enable the tunnel heat to be removed due to train movements. The platform air captured by the trackway exhaust system shall be cooled and recirculated in the station. For less severe (i.e. cool) environmental conditions (or in the event of an AC system failure), station air conditioning will not be used and ventilation shafts will be open to atmosphere (open system) with the trackway exhaust system operating. For cold conditions, the closed system or open system mode may be used without any station air conditioning. System heating is achieved by the train heat released into the premises.
- **Congested Conditions**

  Congested conditions occur when delays cause disruption to the movement of trains. It is possible that the delays may result in the idling of a train in a tunnel section. Without forced ventilation, excessive tunnel temperatures may result reduced performance of coach air conditioners that may lead to passenger discomfort.

  During congested operations, the tunnel ventilation system is operated to maintain a specific temperature in the vicinity of the car air conditioner condenser coils (i.e. allowing for thermal stratification). The open system congested ventilation shall be via a ‘push-pull’ effect where tunnel vent fans behind the train are operated in supply and tunnel vent fans ahead of the trains are operated in exhaust mode. Nozzles or booster (jet) fans will be used to direct air into the desired tunnel, if required.

- **Emergency Conditions**

  Emergency conditions are when smoke is generated in the tunnel or station trackway. In emergency conditions, the tunnel ventilation system would be set to operate to control the movement of smoke and provide a smoke-free path for evacuation of the passengers and for the firefighting purposes. The ventilation system is operated in a ‘push-pull’ supply and exhaust mode with jet fans or nozzles driving tunnel flows such that the smoke is forced to move in one direction, enabling evacuation to take place in the opposite direction depending upon the location of Fire on the train.

  **3.6.8 Pressure Transients**

  The movement of trains within the underground system induces unsteady air motion in the tunnels and stations. Together with changes in cross section, this motion of air results in changes in air pressure within trains and for wayside locations. These changes in pressure or ‘pressure transients’ can be a source of passenger discomfort and can also be harmful to the wayside equipment and structures. Two types of transient phenomenon are generally to be examined:

  a) **Portal Entry and Exit Pressure Transients** – As a train enters a portal, passengers will experience a rise in pressure from when the nose enters until the tail enters. After the tail enters the pressure drops. Similarly, as the nose exits a portal, pressure changes are experienced in the train.

  b) **Wayside Pressure Transients** – As trains travel through the system they will pass structures, equipment and patrons on platforms. Equipment would include cross passage doors, lights, dampers, walkways etc. Pressures are positive for the approaching train and negative for retreating trains.
Most rapid changes occur with the passage of the train nose and tail. The repetitive nature of these pressures may need to be considered when considering fatigue in the design of equipment.

The detailed analysis to assess the effect of pressure transients will be done during the design stage. For the portal entry/exits the effect of higher train speed may pose discomfort to the passengers. The estimation of Way-side transients during design stage would be necessary to select design mechanical strength of the trackside fixtures, e.g. false ceilings, light fittings etc. at the platform levels.

### 3.6.9 Ventilation and Air Conditioning of Ancillary Spaces

Ancillary spaces such as staff room, equipment plant room, will be mechanically ventilated or air conditioned in accordance with the desired air change rates and temperatures/humidity.

All ancillary areas that require 24-hour air conditioning will be provided with fan-coil units (FCU) and standby AC units. During the revenue hours when the main chilled water system is running the FCU will be used for air-conditioning and in non-revenue hours standby AC units will be operated. Return air grilles will be fitted with washable air filters for the re-circulation of the air.

Where fresh air is required it will be supplied to the indoor unit via a fresh air supply system, complete with filter, common to a group of ancillary areas. The fresh air unit will be located in the VAC plant room and will be time switch controlled with local override. Temperature control will include an alarm setting, which is activated on attaining high temperature.

### 3.6.10 System Components for VAC

The various components and equipment used in the VAC system are described in the following sections:

- **Station Air Conditioning**

  The platform and concourse areas will be air-conditioned using supply ‘air handling units’ located in air-handling plant rooms throughout the station. Each platform will be served by at least two separate air handling units (AHU’s) with the distribution systems combined along each platform to ensure coverage of all areas in the event of single equipment failure. Based on the initial estimation about 6 units (2 for the concourse each with 18 cum/s and 4 for the platform each having 24 cum/s air-flow) would be needed for the full system capacity.
These air conditioning systems mix return air with a desired quantity of outside air. The outside air requirement is based on occupancy, with a minimum of 5 litres per second per person or 10% of circulated air volume, whichever is the greater. The provision of free cooling by a simple two-position economizer control system will be included, with the use of enthalpy sensors to determine the benefits of using return air or outside air. This will signal the control system to operate dampers between minimum and full fresh air, so as to minimize the enthalpy reduction needed to be achieved by the cooling coil. This mixture of outside and return air is then filtered by means of suitable filters and then cooled by a cooling coil before being distributed as supply air via high level insulated ductwork to diffusers, discharging the air into the serviced space in a controlled way to minimize draughts. Return air to the platform areas is extracted via the trackway exhaust system and either returned to the AHU’s or exhausted as required.

The concourse air handling unit and platform supply duct from air handling unit is shown in **FIGURE 3.6** and **FIGURE 3.7** respectively.

**FIGURE 3.6: CONCOURSE AIR HANDLING UNIT**

![Concourse Air Handling Unit]

**FIGURE 3.7: PLATFORM SUPPLY DUCT FROM AIR HANDLING UNIT**

![Platform Supply Duct from Air Handling Unit]
Water-cooled chiller units with screw compressors are recommended to be provided at each station, which are energy efficient. These units can be installed in a chiller plant room at surface level or in the underground premises. Based on the initial concept design, the estimated capacity for a typical station would be around 400 TR, hence three units of 200 TR (including one stand-by) may be required for full system capacity (i.e. design PHPDT traffic requirement). This capacity needs to be reaffirmed during the detail design stage for individual station depending on the heat loads. It is recommended that initially two units of 200 TR may be installed with the provision in terms of space be kept for the future addition.

In view of the temperate outdoor conditions, alternatively, it is possible to utilize air-cooled chiller units, which can save large amount of water requirement. The air-cooled chillers should be equipped with screw compressors so that they can be operated at a very less load with high efficiency. These units also eliminate requirement of condenser water circuits including pumps, cooling towers and make up water plants, but are less efficient as compared to the water-cooled- units.

- **Tunnel Ventilation Fans**

As described earlier tunnel ventilation fans will be installed in each of the fan rooms near vent shafts. There shall be two fans in a fan room at each end of the station. The fan capacity depends on the inter-station distances and may vary from 60 cum/s to 100 cum/s. The exact capacity will be obtained through the simulation during detailed design stage. If necessary, nozzle type structures made up of concrete or steel may also be constructed to achieve desired airflow and air velocity in the tunnel sections. Alternatively booster fans (jet fans) may be installed to direct the flow in the desired direction. These fans may also be used for emergency ventilation at crossover locations.

The trackway exhaust system will have two fans of each 30 cum/sec. for each platform. The connections to tunnels and shafts will be through damper units that may be either electrically or pneumatic actuated.

### 3.6.11 Control and Monitoring Facilities

For the underground stations the control and monitoring of station services and systems such as station air-conditioning, ventilation to plant rooms, lighting, pumping systems, lifts & Escalators, etc. shall be performed at Station Control Room (SCR). However, the operation and control of Tunnel Ventilation as well as Smoke Management system will normally be done through OCC. All these systems shall be equipped with automatic, manual, local and remote operation modes. The alarms and signals from the equipment at stations shall be transmitted to the OCC via communication network.
3.6.12 Codes and Standards

The concept VAC design is guided by the following codes and standards:

a) SEDH – Subway Environment Design Handbook
c) CIBSE – relevant document.
e) ECBC – Energy Conservation Building Code

The station air conditioning closed system scheme and section view are shown in FIGURE 3.8 and FIGURE 3.9.
3.7 **E&M Systems**

3.7.1 **LT Power Distribution**

33 kV ring main cables running all along the route shall feed each ASS by loop in loop out arrangement. The 33 kV power supply is stepped down to 415 V, 3 phase for distribution to the consumption points (service utilities) viz. Elevators, Escalators, Light & power sockets, Fire system, HVAC system and Signal & Telecom system etc.

The power distribution system shall be designed by using low voltage power cable run on the cable tray, raceway and conduit as suitable to supply power to various loads within station and buildings. The low voltage power distribution cables shall comply with IEC 60502 or other applicable international standard. Fire resistant cables shall be used for safety purpose and comply with the performance requirements of IEC60331 and BS 6387.

3.7.2 **Illumination System**

For illumination generally, all lighting fixtures shall be applied with 240V, single phase 50Hz power supply. The type and quality of fittings and their luminous intensity shall relate to the space being illuminated and will take into account the effect of architectural space concept and colour scheme as per IS 3646.

The LED lights offer advantages over conventional fluorescent lighting on account of Energy savings, lower life cycle cost, longer life span, rugged nature etc. Considering the benefits of LED light fixtures over the conventional/fluorescent fixtures, the use of LED light fixtures is recommended at elevated and underground stations of the corridor and the office buildings of the depot. However, the conventional fluorescent light fittings may be adopted at selected locations wherever payback period for additional cost of LED light is much higher or non-availability of efficient and proven LED light fixtures such as Medium/High Bay lighting of high wattage (250W – 400W) in depot.

3.7.3 **Lifts and Escalators**

Lifts and escalators shall be provided at each station for the convenience of the passengers. The power supply for the operation of lifts and escalators is fed from the Auxiliary substation at each station. The number of lifts and escalators proposed to be provided for the passengers at each station of Agra Metro corridors is given in **TABLE 3.5**.
TABLE 3.5: REQUIREMENT OF LIFTS & ESCALATORS

<table>
<thead>
<tr>
<th>Corridor</th>
<th>Lift</th>
<th>Escalator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corridor 1: BHU to BHEL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevated Stations</td>
<td>24</td>
<td>16</td>
</tr>
<tr>
<td>UG Stations</td>
<td>29</td>
<td>125</td>
</tr>
<tr>
<td>Total</td>
<td>53</td>
<td>141</td>
</tr>
<tr>
<td>Corridor 2: Benia Bag to Sarnath</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevated Stations</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>UG Stations</td>
<td>17</td>
<td>70</td>
</tr>
<tr>
<td>Total</td>
<td>27</td>
<td>80</td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td><strong>80</strong></td>
<td><strong>221</strong></td>
</tr>
</tbody>
</table>

3.7.4 Fire Detection and Suppression System

The Fire Detection & Alarm System shall be in conformance to the applicable NFPA standard or Other International Standards & also comply with the codes of practice, standards, regulations and requirements of the Statutory Authorities. The coordination of Fire Detection & Alarm System with the following services should be verified, tested, and validated as a complete system before implementation-

i. Fire Detection & Alarm System,

ii. Public Address & Voice Alarm System,

iii. Emergency Lighting System,

iv. Conveying Systems (Lifts & Escalators),

v. HVAC systems (AHUs / fire dampers / staircase pressurization fans / chillers, motorized dampers / exhaust fans etc.),

vi. Fire Fighting Systems (Fire Pumps / Sprinkler Valves),

vii. Automatic Doors,

viii. Traction SCADA,

ix. E&M SCADA,
x. Rolling Shutters,

xi. Networking of main fire alarm system, at station to the station control room, and back net Interface on TCP/IP for third party systems.

xii. Systems not listed above but that requires interfacing with the Main Fire Alarm System.

3.7.4.1 Portable Fire Extinguishers

The portable fire extinguishers shall be installed at all the stations in compliance with relevant BS EN Codes and codes of practice, standards, regulations & requirements of the Statutory Authorities. All the covered areas should be provided with suitable type of fire extinguishers. In the Concourse and Platform areas Fire Extinguishers shall be provided in a central location inside a suitably sized cabinet of approved construction. The location and design of the extinguisher cabinets provided shall comply fully to the local fire authority requirements.

Extinguishers shall be conspicuously located in positions where they will be readily accessible and immediately available in the event of fire. They shall be located near to room exits, corridors, stairways, lobbies and landings. Extinguishers shall be installed at a height of 1 metre above the floor level and shall be placed in a manner such that the extinguisher operating instructions face outward.

3.7.4.2 Wet Mains System

The Fire Fighting wet mains system shall be based on BS- 9990: 2006, BS-9999: 2008 & National Building Code. The system shall comprise pipe work, breeching inlets, landing valves, automatic air release valves, fire hose cabinets and fire hose reels etc.

The wet mains system is charged by the Fire pumps set. The fire pump set shall have dual power supply and the system shall be designed to achieve a pressure of 3.5 Bar at the remote fire hydrant point. The system will draw water from the fire water storage tank provided near station building based on the NBC requirements.

3.7.4.3 Fire Hose Cabinet

The Fire Hose Cabinets shall be provided as per NBC and fire authority regulations in internal and external public areas of the station.

3.7.4.4 Fire Hose Reels

The hose reels shall meet the requirements of BS 5306.1: 2006 & BS EN 671 – 3:2004. Hose-reel shall be provided in such a way that it covers the entire Concourse / Platform
areas with suitable number of fire hose cabinets. The hose reels system will be based on direct feed from the Fire Water Wet mains.

Hose-reels shall be of the swing-recessed type. Each hose-reel shall be an integral unit consisting of a stop valve, reel, hose, and shut-off assembly. It shall be designed so as to facilitate the swift withdrawal of the hose in any direction with the reel axis horizontal.

3.7.5 **Gas Flooding System**

Gas Flooding System is proposed to be provided for protection of the equipments in electrical Auxiliary sub-stations and S&T Equipments in Depot Control Centre/Operational Control Centre. The design of the system shall be in conformance to NFPA standards.

3.8 **Solar Energy Harnessing System**

3.8.1 **Introduction**

The solar mission, which is part of the National Action Plan on Climate Change has been set up by Govt. of India to promote the development and use of solar energy for power generation and other uses with the ultimate objective of making solar energy competitive with fossil-based energy options.

Considering the futuristic technology and potential for solar power generation, Delhi Metro has recently implemented roof top grid connected solar power systems at selected locations of elevated stations and maintenance depot. Metro Railways under implementation in different cities of the country viz. Jaipur, Lucknow, Nagpur etc. are also exploring the possibilities of harnessing solar photovoltaic energy.

With the downward trend in the cost of harnessing solar energy and appreciation for the need for development of solar power, provision of a grid connected solar photovoltaic power plant utilizing all possible areas viz. roof top of stations/sheds and buildings is proposed for Varanasi MRTS.

3.8.2 **Solar PV Power Generation Potential**

The roof top on the elevated stations of Varanasi Metro corridors and the different sheds and buildings of the depot viz. Stabling, Inspection and Heavy Repair Shed, Administrative Building, Training Centre, DCC/OCC Building etc. is proposed to be used for SPV installation at suitable orientation and inclination to optimize the solar energy potential. The roof of the sheds should be south facing to maximize the solar power generation in depot. The solar power would be used locally to the extent of load in the building and the generation over and above the requirement of the building would be fed into the grid.
The average raw sunshine available which can be harnessed for the power generation depends on the geometrical coordinates of the place. The intensity of solar radiation varies with time of the day. The combined effect of these factors and the additional complication of the wobble of the seasons is that the average raw power of sunshine per square meter of south-facing roof in India is roughly 100 to 120W/m².

The mean global solar radiant exposure at Varanasi varies from 3.7 kWh/m²/day in the month of December to 6.6 kWh/m²/day in the month of May.

Based on the solar radiation intensity in the city of Varanasi, the peak solar power generation of Varanasi Metro corridor is expected to be about 50kWp for the elevated stations and about 2000kWp for maintenance depot.

The power generation depends upon various factors such as the intensity of the solar radiation, the net useable area available on the roof top, the obstructions due to shadow or the shading factor, the orientation of the solar panels, efficiency of the solar cells etc. The solar power generation potential in Varanasi metro corridors is required to be reviewed and finalized during detail design stage.

3.9 SIGNALLING SYSTEM

3.9.1 Introduction

The signalling system shall provide the means of an efficient train control ensuring safety in train movements. It assists in optimization of metro infrastructure investment and running of efficient train services on the network.

3.9.2 Design Parameters

- Ridership 24000 PHPDT(Corri.-I)/18000 PHPDT(Corri.-II)
- Standard Gauge 1435 mm
- Average Speed 35 Kmph (Corri.-I)/34 Kmph (Corri.-II)
- Corridor Length 19.4 Km (Corri.-I)/9.9 km(Corri.-II)
- Total Stations 17(Corri.-I)/9(Corri.-II)
- Train Configuration 3 Car Rake
- Required Headway 144 Seconds (Corr.-I)/ 192 Seconds (Corr.-II)
3.9.3 Options for Signalling Systems

Depending on type of the Railway Network, Main Line or Metro Rail, Signalling & Train Control can be achieved by adopting any of the following Signalling System / Technologies available:

- Automatic Signalling
- ETCS Level – 1
- ETCS Level – 2
- Distance to Go (DTG)
- Communication Based Train Control (CBTC)

While systems at S.No. (i) – (iii) have been developed / used for Main Line Railway networks, systems at S.No. (iv) – (v) are for Metro Railway Networks. Therefore, to have a fair idea of the Signalling & Train Control systems for metro railway, the relative merits & limitations of Distance to Go (DTG) and Communication based train control system (CBTC) are discussed as below:

a) Distance to Go (DTG) Signalling System:

Distance to Go (DTG) signalling system is mainly used for MRTS systems and adopted by most of the recently commissioned MRTS systems in India viz. DMRC (Delhi Metro) Phase-I, Phase-II, Delhi Airport Metro Express Line, BMRCL Phase-I (Bengaluru Metro), JMRCL (Jaipur Metro) & Chennai Metro.

It has advanced features of Continuous Automatic Train Control (CATC) consisting of sub-systems like Automatic Train Supervision (ATS), Automatic Train Protection (ATP) and Automatic Train Operation (ATO).

These sub-systems are briefly described below:

- **Automatic Train Supervision (ATS)**

Automatic Train Supervision (ATS) is used to provide overall control of trains operation and remote control of the station. The main function of ATS is automatic management of train’s movement by interfacing with ATP / CBI systems for route setting, train supervision and regulation. The system supervises train movements continuously and optimizes train movements in case of abnormalities. ATS system also logs each train movement and displays it on traffic controller work stations and over view display panel...
at the OCC and also on workstations placed in the Station Control Room (SCR) for Station Controller.

- **Automatic Train Protection (ATP)**

  Automatic Train Protection (ATP) system (both on-board and way-side) in conjunction with Electronic interlocking, track profile and brake characteristics of rolling stock is provided to ensure safe as also optimal train services on the section. ATP system includes continuous transmission of various safety parameters (authorized speed, movement authority etc.) from track to train through coded audio frequency track circuit. This information received from way-side ATP systems by on-board ATC system provides Cab signalling i.e. display of maximum safe speed, current speed and target speed / distance. Facilities for automatic enforcement of temporary / permanent speed restrictions are also built in to enhance safety during maintenance work.

- **Automatic Train Operation (ATO)**

  Automatic Train Operation (ATO) operates the trains automatically from station to station within the safety envelope / parameters of ATP & also controls (opens / closes) the train doors. Train Operator (TO) is only required to Close the train doors and press a Start button when train is ready to depart. ATO in conjunction with ATP & ATS can control / regulate running & dwell time at stations in accordance with headway / timetable regulation and also regulates the automatic reversal/turn back of trains at terminal stations.

- **Pros and Cons of DTG (Distance to Go) Signalling System:**

  The Distance to Go (DTG) Signalling system provides safety level of CENELEC SIL-4 (Safety Integrity Level) and permits an operational headway of 2.5 Minutes with Continuous Automatic Train Control. DTG works on fixed block principle. It needs Audio Frequency Track Circuits (AFTC) for train detection and track to train communication. The reliability of the system depends on the reliability of AFTC.

  With the advent of Communication Based Train Control (CBTC) at almost same cost, metro transport authorities / organizations are now favouring adoption of CBTC over DTG based Signalling System for all new projects. World over, for new MRTS projects, while adoption of DTG based systems is on a decline, adoption of CBTC based systems, because of their advanced features and low life cycle costs, are increasing steadily. In conclusion while DTG based System can be considered technology of the past, CBTC based system can be considered technology for the present & future.

  The Distance to Go (DTG) Signalling system costs around Rs. 6.7 Crores per km based on costing of BMRCL contract no. 2-S&T-DM of June'2009.
Considering the high cost of Distance to Go (DTG) Signalling system and advent of new technology viz. Communication Based Train Control (CBTC), which supports advance features such as Unattended Train Operation, moving block etc. and is available at almost same cost, Distance to Go (DTG) Signalling system is NOT recommended for Varanasi Metro corridors.

b) Communication based Train Control (CBTC) Signalling System:

Communication based Train Control (CBTC) Signalling System is mainly used for MRTS networks. It is the latest Signalling and Train Control Technology available and is being adopted by modern metros around the world. It is also being adopted by all upcoming MRTS Networks in India viz., DMRC Phase-III, Kochi Phase-I, BMRCL Phase-II etc.

Communication based Train Control (CBTC) Signalling System also has ATP, ATS, ATO/UTO functionality and works on the Moving or Virtual Block principle to reduce headways and increase transport capacity. CBTC relies on continuous two-way digital communication between each controlled train and a wayside control centre. On a moving block equipped railway, the line is usually divided into areas or regions, each area under the control of a computer and each with its own radio transmission system. Each train transmits its identity, location, direction and speed to the area computer which makes the necessary calculations for safe train separation (moving authority) and transmits this to the following train.

The radio link between each train and the area computer is continuous so the computer knows location of all the trains in its area all the time. It transmits to each train the location of the train in front and gives it a braking curve to enable it to stop before it reaches that train. In effect, it can be termed as a dynamic Distance-to-Go system.

As the CBTC based system has very few way side equipment and supports UTO, total life cycle cost of the system shall be substantially lower than other Signalling Systems due to low Maintenance & Operation (man power) costs.

Pros and Cons of CBTC Signalling System:

The Communication based Train Control (CBTC) signalling system provides adequate safety level of CENELEC SIL-4 (Safety Integrity Level) and permits an operational headway of 90 seconds with continuous automatic train control. The CBTC Technology is proven now in many Metros around the World and is also suitable for UTO (Unattended Train Operation) / DTO (Driverless Train Operation).

If UTO system is considered for adoption, then provision of PSD (Platform Screen Doors) shall also have to be considered as it is a mandatory safety requirement for UTO operations.
The Communication based Train Control Signalling system costs around **Rs. 6.66 Crores per km.** The cost is as per Kochi Phase – I LOA of Dec’2014 awarded to M/s Alstom for Aluva-Petta Corridor.

After reviewing all available Signalling & Train Control Signalling Technologies, Communication based Train Control (CBTC) system, which is the latest technology available, is recommended for Varanasi Metro corridor.

### 3.9.4 Standards

**TABLE 3.6** below shows the standards that will be adopted with regard to the Signalling system.

<table>
<thead>
<tr>
<th>Description</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>CBTC System</td>
<td>IEEE 1474.1</td>
</tr>
<tr>
<td>Operation of Points</td>
<td>With Direct current 110V D.C. point machines or 380 volts 3 phase, 50 Hz. AC point machines.</td>
</tr>
<tr>
<td>Fail Safe Principles</td>
<td>SIL4 safety levels as per CENELEC standard for signal application.</td>
</tr>
<tr>
<td>Immunity to External Interference.</td>
<td>All data transmission on telecom cables/OFC/Radio. All Signalling and telecom cables will be separated from power cables. CENELEC standards to be implemented for EMC.</td>
</tr>
<tr>
<td>Fall Back System</td>
<td>Digital Axle Counter</td>
</tr>
<tr>
<td>Other Items</td>
<td>Suitable International Standards like CENELEC etc. shall be followed as per good industry practices.</td>
</tr>
</tbody>
</table>
3.10 TELECOMMUNICATION SYSTEM

3.10.1 Introduction

The telecommunication system acts as communication backbone for Signalling and other systems and provides telecommunication services to meet operational and administrative requirements of metro network.

3.10.2 Telecommunication System used in other Metros

The telecommunication system used in different Metros are as given in TABLE 3.7 below:

**TABLE 3.7: TELECOMMUNICATION SYSTEM USED IN DIFFERENT METROS**

<table>
<thead>
<tr>
<th>Metro Operator</th>
<th>System Used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DMRC</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Line 1         | A Digital Transmission System (DTS)  
                  Optical Fiber Cable  
                  Main Telecommunications Bearer: SDH - STM 4 155Mbps network  
                  B Telephone System : EPABX  
                  C Mobile Radio Communications: Digital Trunk Radio System (TETRA)  
                  D Public Address (PA) System  
                  E Centralized Clock System: Digital & Analog Clocks and Time Synchronization System  
                  F Passenger Information Display System: LED based  
                  G Network Management & Station Management System  
                  H CCTV Cameras were provided later on for Security purposes |
| Line 2         | Same as above with Closed Circuit Television: fixed and PTZ Camera and PIDS LED and LCD based. |
| Line 3 Phase II|             |
| **BMRCL**      |             |
| Phase I        | A Digital Transmission System (DTS)  
                  - Optical Fiber Cable  
                  - Main Telecommunications Bearer: SDH - STM 4 155Mbps network  
                  B Telephone System : EPABX  
                  C Mobile Radio Communications: Digital Trunk Radio (TETRA)  
                  D Public Address System  
                  E Centralized Clock System: Digital and Analog Clock System  
                  G Closed Circuit Television System : Fixed and PTZ Camera with monitors  
                  H             |
3.10.3 Proposed Telecommunication System and Transmission Media

The state of the art latest technology being used in different metros worldwide is proposed to be used for the Varanasi MRTS. The Telecommunication System Structure is shown in **FIGURE 3.10** below:

### 3.10.4 Digital Transmission System (DTS)

#### 3.10.4.1 Optical Fibre Cable - Main telecommunication bearer

GE (Giga Ethernet) based IP system is proposed for the entire telecom network. OFC backbone network shall be formed by laying two outdoor single mode optical fibre cables (to be laid on either side of tracks). The normal and protected routes shall arrange in two different cables for path diversity. Considering the channel requirement and keeping in view the future expansion requirements a minimum 144 Fibre, optical fibre cable is proposed to be laid in ring configuration with path diversity.
FIGURE 3.10: TELECOMMUNICATION SYSTEM STRUCTURE

[Diagram of telecommunication system structure showing OCC, Transport Level, Track Level, Station Level, and Train Level with various components such as OCC, PABX, Radio, CCTV, CLS, UPS, PAS, Content Mgt, Operation Desks, Asset Mgt SCADA, 1. FOTS - SDH BACKBONE, 2. PABX, 3. RADIO, 4. PAS, 5. CCTV, 6. CLS, 7. UPS, 8. PIDS, Infotainment, Monitoring & Staff Services, Passenger Services.]
Additional OFC can be considered to be provided if there is a demand for leasing Fibre from Telcos / Industries, providing a source of revenue generation.

The IP network shall consist of highly reliable and fault tolerant Layer-2, Layer-3 and Access switches configured with due redundancy both at Back bone and Access levels for the MAN/LAN. The switches shall have IP interface cards of 10 GBPS for backbone, 1 GBPS for interface with all telecommunication and non-telecommunication sub-systems and 2 MBPS and higher levels for access level. All interfaces with other sub systems shall be IP based with minimum 2 MBPS capacity.

### 3.10.4.2 Telephone Exchange

A cost effective solution of an Hybrid PBX which supports both Digital & IP Telephones, having at least 50 extensions will be provided at each station and 500 extensions PBX will be provided at the central, intermediate location on corridor and depot. The Exchanges will serve the subscribers at all the stations, OCC and depot. Capacity of Exchanges can be suitably augmented if required, depending on available subscribers. The exchanges will be interconnected at multiple IP interfaces (2 MBPS) through redundant optical fiber cable paths.

### 3.10.4.3 Mobile Radio Communication

Mobile Radio communication system having minimum 8 logical channels is proposed for on-line emergency communication between Motorman (Front end and Rear end) of moving train and the Central Control. The system shall be based on Digital Trunk Radio Technology to TETRA International standard. All the stations and the OCC will be provided with fixed radio sets. Mobile communication facility for maintenance parties and Security Personnel will be provided with handheld sets. These persons will be able to communicate with each other as well as with central control as shown in **FIGURE 3.11**.

**FIGURE 3.11 TRAIN CAB RADIO AND COMM. FACILITY FOR MAINTENANCE**

The frequency band for operation of the system i.e. 410-430 or 380-400 MHz may be taken as per availability. The system shall provide mobile radio communication between
the motorman of the moving cars from any place and the Central Control. The motorman can also contact any station in the network through the central control, besides intimating the approaching trains about any emergency like accident, fire, line blocked etc., thus improving safety performance.

To provide adequate coverage, based on the RF site survey to be carried out during detailed Design stage, base stations for the system will be located at sites conveniently selected after detailed survey.

In addition to the TETRA Radio Coverage for the internal use of the Metro, the city is also having Mobile Coverage from Private Operators.

3.10.4.4 Public Address System

The public Address System shall be capable of digitized voice announcements and long range PA functionality suitable for evacuation situations in emergency. The public address system at stations will generally operate in automatic mode providing information for the time and destination of the next schedule train, special upcoming event, safety and security announcement at pre-determined intervals and general information to enhance the travel experience for all users but more specially the visually impaired.

3.10.4.5 Centralized Clock System

The Clock System shall provide synchronized time for the whole Rail system. The time source shall be obtained from Global Positioning System (GPS). The synchronized time information shall be displayed on slave clock units and provided to all other sub systems including signalling & AFC via the Digital Transmission System as shown in FIGURE 3.12.

FIGURE 3.12: MASTER CLOCK
3.10.4.6 Passenger Information Display System

At all stations, suitable Electronic Passenger Information Display Boards preferably LCD/LED (Flat Panel) will be provided as shown in FIGURE 3.13. The PIDS shall be train actuated (controlled by signalling system) along with facility for manual inputs from the local station as well as the central location (OCC).

FIGURE 3.13: PASSENGER INFORMATION DISPLAY SYSTEM

Passenger Information display boards will be provided at convenient locations at all stations to provide bilingual i.e. Hindi & English visual indication of the status of the running trains and will typically indicate information such as destination, platform numbers, arrival/departure time, and also special messages in emergencies. The boards will be provided at all platforms and concourses of terminal & junction stations as shown in FIGURE 3.14.

FIGURE 3.14: PIDS AT PLATFORM AND CONCOURSE
It is envisaged that Public Address and Passenger Information Display System is provided in the car so that passengers are continuously advised of the next stoppage station, final destination station, interchange station, emergency situations if any, and other messages. The rolling stock is provided with Talk Back Units inside the cars, which permit conversation between passengers and the drivers in case of any emergency.

### 3.10.4.7 Close Circuit Television

CCTV system should ensure real time full coverage, high quality surveillance of all public and selected areas such as tunnel cross passages, ancillary buildings, on board conditions for secure passenger management, crowd control and other emergency situations. Event reloading shall be possible for post video analysis. CCTV cameras shall also be provided in Operational rooms like OCC, SCR etc. A proper IP based recording and storing facility to record and store events for minimum of one month shall be ensured.

### 3.10.4.8 Central Voice Recording System (CVRS)

A centralized digital voice recording system will be provided at OCC to record all Two-way Telephone conversation, PA calls from station and OCC, Two Way Radio Conversation of all controllers, TOs, SCRs and other users in OCC and Depot. In addition all conversation of the Radio System including private calls of all subscribers including Controllers, TOs shall also be recorded. Arrangement of free space audio recording in OCC, SCRs and Driver Cab shall also be made available.

### 3.10.4.9 Central Fault Reporting System (CFRS)

For efficient and cost effective maintenance of the entire communication network, it is proposed to provide a CFRS / SCADA system which will help in reporting and diagnosing the faults immediately from a central location and attending the same with least possible delay, thus increasing the operational efficiency and reduction in manpower requirement for maintenance.

### 3.10.4.10 WiFi Services

The Wi-Fi services are proposed to be provided at stations as well as on-board to the passengers. The passengers have to search the available wifi network of metro and after registering their mobile number, they will get login ID and password through SMS. After receiving the login ID and password, passengers can access the Metro Wi-Fi network irrespective of their mobile network operator.
3.10.4.11 LED Display Walls

Two (02 nos.) of LED Display walls having size approximately 2.88m (W) x 1.92 m (H), (5.52 Sq. Mtrs) each are proposed to be provided at suitable locations at all platforms. The outdoor LED displays may be used to run the commercials as well as other useful passenger information as per requirements.

3.10.4.12 Uninterrupted Power Supply

The uninterruptible power supply (UPS) of 60 KVA, 415 V ± 1%, 3 phase with Battery bank of 800AH capacity at each interlock station and 30 KVA with Battery bank of 300AH capacity at each non interlock station will be provided for 2 hour back up.

The standards that will be adopted with regard to the Telecommunication systems are shown in TABLE 3.8 as below. These will conform to appropriate IRS/International standards.

**TABLE 3.8: STANDARDS TO BE ADOPTED FOR TELECOMMUNICATION SYSTEMS**

<table>
<thead>
<tr>
<th>Description</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmission System</td>
<td>GE (Giga Ethernet) based IP system for the entire telecom network. OFC backbone network shall be formed by laying two outdoor single mode optical fibre cables (to be laid on either side of tracks). The normal and protected routes shall arrange in two different cables for path diversity.</td>
</tr>
<tr>
<td>Optical Fibre cable</td>
<td>OFC for underground environment shall be steel armoured and manufactured from Fire Retardant/resistance, Low Smoke and zero halogen materials. For elevated portion of corridor, it shall be steel armoured and conforming to IRS specifications.</td>
</tr>
<tr>
<td>Public Address System</td>
<td>Passenger Announcement System shall be interfaced with signalling system for online update of train information.</td>
</tr>
<tr>
<td></td>
<td>IEC 60268 as applicable or any equivalent international/National standard.</td>
</tr>
<tr>
<td></td>
<td>The methods of measurement for variation in parameters for the equipment shall be in accordance with IEC 268 Part 1 to 17 – Sound System Equipment.</td>
</tr>
<tr>
<td></td>
<td>Fire resistant Low Smoke Zero Halogen cables shall be used to maintain the circuit integrity in case of fire.</td>
</tr>
<tr>
<td>Telephone Exchange</td>
<td>Hybrid Exchange (supports both digital &amp; IP Telephones)</td>
</tr>
<tr>
<td>----------------------------------------</td>
<td>--------------------------------------------------------</td>
</tr>
<tr>
<td>Passenger Display Information System</td>
<td>It shall be interfaced with signalling system for online update of train information.</td>
</tr>
<tr>
<td></td>
<td>IEC as applicable or any equivalent international/National standard.</td>
</tr>
<tr>
<td>Synchronized Clock system</td>
<td>GPS based, master – slave system IEC 61588 or equivalent standard</td>
</tr>
<tr>
<td>CCTV/ Camera</td>
<td>CCTV network shall be as per IEEE standards.</td>
</tr>
<tr>
<td></td>
<td>IP based fixed and PTZ CCTV Cameras.</td>
</tr>
<tr>
<td></td>
<td>External storage device with RAID 5 protection.</td>
</tr>
<tr>
<td>Redundancy (Major System)</td>
<td>Redundancy includes server level for all communication sub-systems.</td>
</tr>
<tr>
<td>Environmental Conditions</td>
<td>All equipment rooms to be air-conditioned.</td>
</tr>
<tr>
<td>Maintenance Philosophy</td>
<td>System to have, as far as possible, automatic switching facility to alternate routes/circuits in the event of failure. Philosophy of preventive checks of maintenance to be followed. System networked with NMS for diagnosing faults and coordination. Card/module level replacement will be done in the field and repairs undertaken in the central laboratory/manufacture’s premises.</td>
</tr>
</tbody>
</table>

### 3.11 Automatic Fare Collection System

#### 3.11.1 Introduction

Mass Rapid Transit System handles large number of passengers. Ticket issue and fare collection play a vital role in the efficient and proper operation of the system. To achieve this objective, ticketing system shall be simple, easy to use/operate, easy on accounting facilities, capable of issuing single/multiple journey tickets, amenable for quick fare changes and require overall lesser manpower. Automatic fare collection system meets these requirements. Fare collection technology development is as shown in **FIGURE 3.15** below.
3.11.2 Proposed Automatic Fare Collection System

Keeping in view Metro Railways Automatic Fare Collection System and the fact that Contactless card/token technology proves to be cheaper than other technologies in life cycle cost due to reduced maintenance as it has less wear and tear and is less prone to dusty environment, it is proposed to provide computer based automatic fare collection system with Contactless smart token/card type ticketing for the Varanasi MRTS.

The equipments for the same may be provided at each station viz. Automatic Fare Gates, Ticket Office Machines, Ticket Readers, Portable Ticket Decoders, Central and Station Computers, Passenger Operated Machines/Ticket Vending Machines (POMs/TVMs) and UPS. The typical AFC System Operation Process and Architecture is shown in FIGURE 3.16 and FIGURE 3.17 respectively.

FIGURE 3.16: AFC OPERATION PROCESS
The AFC system shall be interoperable with AFC systems to be planned in future. The AFC system shall also have functionality of interface to CCHS (Central Clearing House System) facility including CCHS hardware and software with provision of integration with other transit (metro, bus etc.) and non-transit (parking, toll etc.) which may be planned in future in line with the state / national policy.

In addition, the proposed AFC system shall also be NFC (Near Field Communication) enabled so that customers can use their NFC enabled Mobile phones for metro travel. Facility of recharging of Travel Cards using Cash, Debit/Credit Cards and Net banking/web portal shall also be available. AFC system shall also support offsite sales terminals also, wherein cards and tokens can be dispensed at locations outside metro premises.

**FIGURE 3.17: AFC SYSTEM ARCHITECTURE**

3.11.3 Recent Technology Development in India

**A. Bank operator : AFC Ticketing system**

Recent developments in the mass transit and financial payments industries have created opportunities for convergence and collaboration.

The Banks are thus too keen to enter into the transit market. In the present dispensation the banks are only acting as a partner to distribute the combo cards. The ownership of card lies with bank, but the transit product on the card is owned by transit operator. Probably we can think of giving preferential treatment to passengers having links with acquirer Bank e.g. separate queue so that we reduce the rush at the counters. Banks will see this as value addition and probably will pay higher royalty.

The scope of banks is to provide the following services:
Providing POS terminals at ticket counters and Automatic Ticket Vending machines

Topping-up of smart cards at ATMs

Topping-up of smart cards through Net banking and Mobile banking

Topping-up of smart cards through Payment gateway at website

Topping-up of smart cards through Auto-top up using Standing Instructions from Bank customers / commuter.

FIGURE 3.18: BANKING INTERFACE

B. Common Mobility Card

Common Mobility Card (CMC) Smart Card will provide Common Fare Collection System across different operators (both Government and Private) and different modes of public transport. Tipped as a nationwide interoperable transport card, the card aims to be a single point of transaction, applicable in state buses, Metro and even parking. The whole system overview is as below:
C. Near Field Communication (NFC)

It is a Wireless communication technology based on inductive-coupling, enables data transfer between machines and Uses the concept of Radio Frequency Identification (RFID). RFID is a technology that does communication through radio waves, that exchanges data between electronic tags put on an object and a reader. NFC works using magnetic induction between two loop antennas located within each other’s ‘near field’ and its operating frequency is 13.56 MHz. data rate 106 kbit/s to 424 kbit/s. NFC use an initiator and a target; the initiator actively generates an RF field that can power a passive target.

3.11.4 AFC system equipment standards

The standard equipment proposed for AFC systems are given in the TABLE 3.9 as below:
### TABLE 3.9: STANDARDS PROPOSED FOR AFC SYSTEMS

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Description</th>
</tr>
</thead>
</table>
| Fare media                       | **Contactless smart token** – For single journey. It will have stored value amount for a particular journey. Tokens will be captured at the exit gate.  
**Contactless smart card** – For multiple journeys. |
| Gates                            | Computer controlled automatic gates at entry and exit. There will be following types of gates:  
Entry  
Exit  
Reversible – can be set to entry or exit  
**Disabled** – Wide reversible gate for disabled people. |
| Station computer, Central computer and AFC Network | All the fare collection equipments will be connected in a local area network with a station server controlling the activities of all the machines. These station servers will be linked to the central computer situated in the operational control centre through the optic fibre communication channels. The centralized control of the system shall provide real time data of earnings, passenger flow analysis, blacklisting of specified cards etc. |
| Ticket office machine (TOM/EFO)  | Manned **Ticket office machine** may be installed in the stations for selling cards/ tokens to the passengers.                                                                                             |
| Ticket reader and portable ticket decoder. | **Ticket reader will** be installed near EFO for passengers to check information stored in the token / cards.                                                                                             |
| Ticket Vending Machine (TVM)     | **Ticket Vending Machines (TVMs)** having facility of issue of single journey tokens & recharge of travel cards using cash, debit/credit cards shall be installed in non-paid areas. |
3.12 Platform Screen Doors

Platform Screen Doors (PSD) is mainly provided at the metro stations to ensure safety and comfort of passengers. The principle advantages of Platform Screen Doors are:

i. It prevents accidental falls off the platform onto the lower track area, suicide attempts and homicides by pushing.

ii. It prevents or reduces wind felt by the passengers caused by the piston effect which could in some circumstances make people fall over.

iii. It reduces the risk of accidents, especially from service trains passing through the station at high speeds.

iv. It improves climate control within the station especially underground stations (heating, ventilation, and air conditioning are more effective when the station is physically isolated from the tunnel).

v. It improves security - access to the tracks and tunnels is restricted.

vi. It lowers operating costs- eliminate the need for motormen or conductors when used in conjunction with Unattended Train Operation (UTO).

vii. It prevents litter build up on the track, which can be a fire risk.

viii. It improves the sound quality of platform announcements, as background noise from the tunnels and trains that are entering or exiting is reduced.

There are some disadvantages of Platform Screen Doors, which are indicated below:

i. Primary disadvantage is their cost; installing a system typically costs approx. 20 million INR per platform.
ii. When used to retrofit older systems, they limit the kind of rolling stock that may be used on a line, as train doors must have exactly the same spacing as the platform doors; this results in additional costs due to depot upgrades.

iii. They impede natural ventilation, increasing climate control costs.

Since the advantages far outweigh the disadvantages, Platform Screen Doors (PSD) are proposed to be provided at all the stations of Varanasi Metro to ensure safety & comfort of commuters. The broad outline/details of Platform Screen Doors (PSD) is described hereunder:

3.12.1 System configuration

The PSD’s comprise Platform Screen Doors (PSD), Manual Secondary Doors (MSD), Emergency Escape Doors (EED) and Fixed Screens (FS) to form a glazed barrier along the edge of the platform for the passenger area. The configuration and location of the EED’s and FS will be such that the PSD’s will correspond to the location of the train doors when the train has berthed in the Correct Stopping Position (CSP) at the platform.

(i) Platform Screen Door (PSD)

These powered glass doors are located along the platform at the platform edge throughout the passenger area and door locations are corresponding to the train car passenger door locations. Opening/closing of the PSD will be after receipt of the doors open/doors close command signals from the Signalling Link. Signalling link enables automatic operation of PSD only when the train stops within ±300 mm limits.

![PLATFORM SCREEN DOOR](image)

(ii) Manual Secondary Door (MSD)
These are manual glass doors located at one end of platform providing access from the platform onto the trackside. In case of emergency evacuation from tunnel/trackside the MSD can be opened from the trackside by using a push bar. The door will be designed to swing open and be held at an open position of 90°. The door will be self-closing to the closed and locked position safely upon the opening position less than 90°, without need for staff intervention. Operation of the MSD is the same as for the EED.

**FIGURE 3.22: MANUAL SCREEN DOOR**

(iii) Emergency Escape Door (EED)

EEDs are located around PSDs of leading and trailing passenger cars. If the train does not stop at the correct position and opened train doors are not in front of PSD doors, the train passengers can go to the platform after opening the EED by pressing the emergency push bar located on the track side of the EED. Operation of the EED is the same as for the MSD.

**FIGURE 3.23: EMERGENCY ESCAPE DOORS & FIXED SCREENS/PANELS**
3.12.2 Fixed Screens/Panel (FP)

Platform length sections not provided with any of PSD/EED/MSD i.e. fixed panels are provided with fixed glass screens called "Fixed Panel" (FP). Apart from acting as a safety feature for the passengers from falling off on the tracks, PSDs also help in reducing the power consumption for the station HVAC and reduce the track-side noise on the platform.

3.12.2 System description and performance

The barrier formed by the PSDs shall be designed and constructed to screen the trackside area from the platform area. In the closed position, each door will be locked to prevent passenger access from the platform. Each door is provided with key device on the platform side for manual opening by the platform staff. The PSDs shall be designed to limit any noise transmitted from the trackside to the platform to NC45 when measured 1m from the edge of any platform. The PSD structure shall be capable to withstand the crowd load from the passengers, the train pressure load, the impact load and the seismic load. These loading may be determined during the detail design. The PSD shall be installed as close to the train kinematic envelope as possible to minimize the gap between the outside of the PSD and the train. The PSD equipment shall have Design Life for a period of 30 years.

(i) Door Locking Mechanism

The locking mechanism of PSD does not engage in presence of any obstruction. Each PSD is fitted, on the track-side, with an easily accessible manual release device to allow passengers leaving the train to disengage the automatic drive and open the door manually.

The manual release on each door panel (PSD/EED/MSD) is easily accessible from the platform side by use of a special keys held by the station staff.

(ii) Door Operation and Control

Door Operation is controlled remotely from the train driver console of a correctly berthed train or from a PSD Local Control Panel (PSL) located in the non-revenue platform headwall/Tail wall area.

Door operating and control arrangements shall be designed to fail in a safe condition which is typically the closed position. Provision shall be made for an audible warning to be given prior to the doors closing. A visual indication lamp shall also illuminate above each doorway when a PSD door-set has not been locked.

(iii) PSD Emergency Power Supply

February, 2016
Back-up power to the PSD shall be provided via a UPS capable of providing 30 minutes of quiescent load to all DCUs plus at least two complete door Open/Close cycles by all driven doors.

### 3.12.3 Options & Recommendations

There are mainly two options for providing Platform Screen Doors viz. Full height PSD or Half height PSD. The advantages & limitations of PSD have been brought out in Section 3.10.

**FIGURE 3.24: HALF HEIGHT PSD**

**FIGURE 3.25: FULL HEIGHT PSD**
Considering the fact that:

- Half-height platform gates are cheaper to install than full height platform screen doors, which require more metallic framework for support.

It is recommended to provide half height Platform Screen Doors at all the stations of Varanasi Metro.