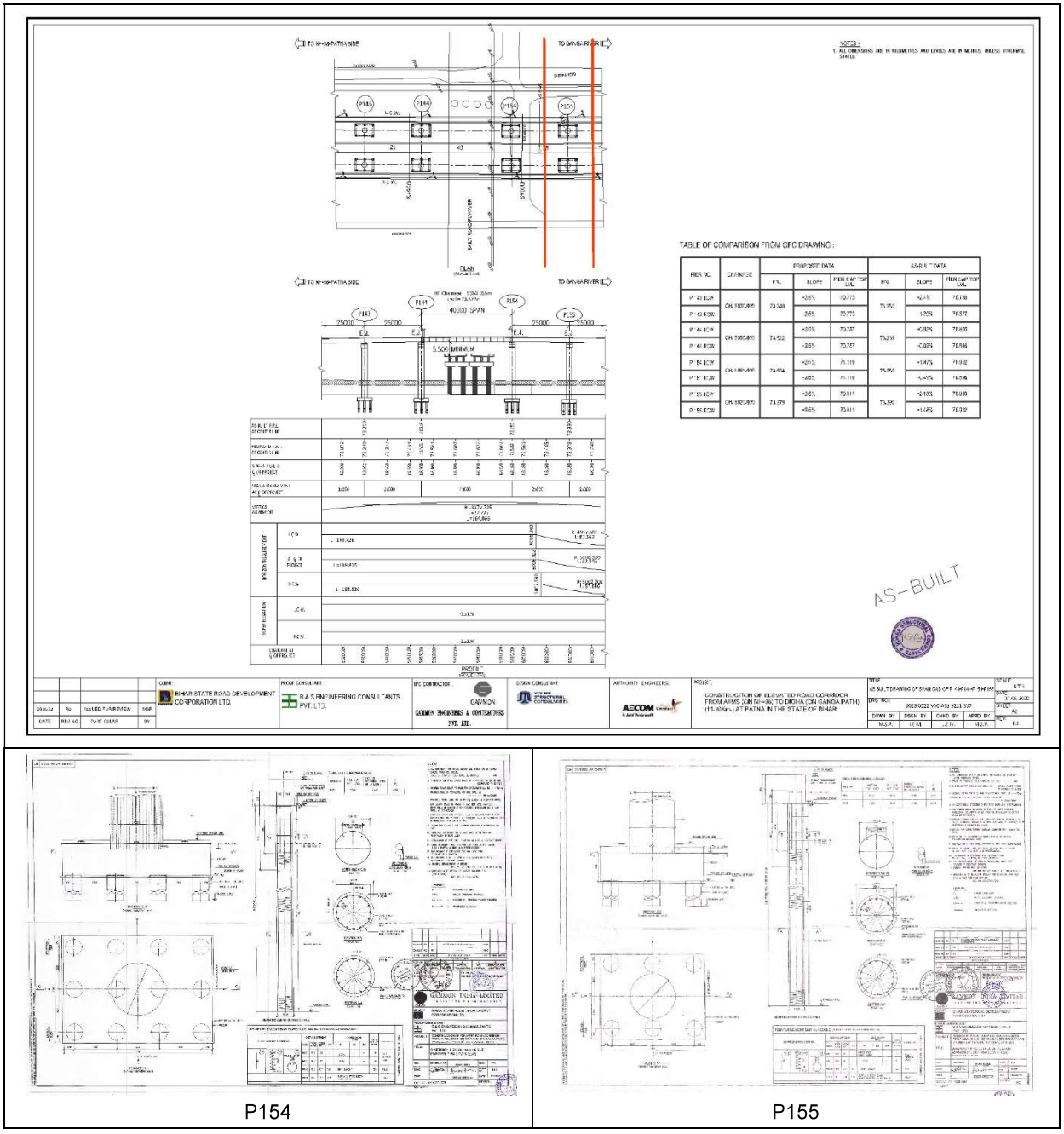



P154 P155

Source: PMRCL/DMRC

**Figure 5-46: As-build Drawing of Patriputra Bridge**

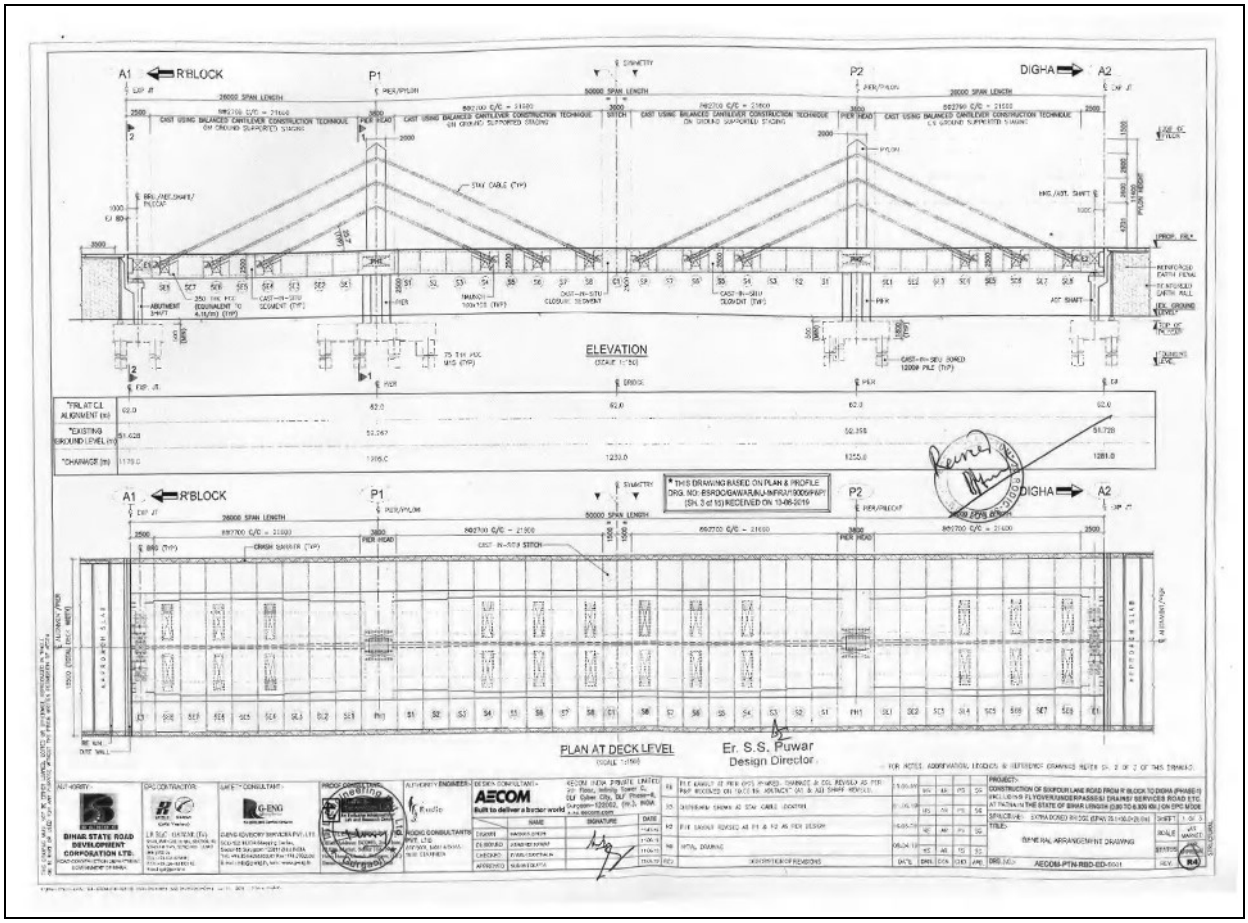
### 3) Feet Road bridge

Distance between TBM machine and pier of the Feet road bridge was confirmed.




Source: JST

**Figure 5-47: Feet Road Bridge**

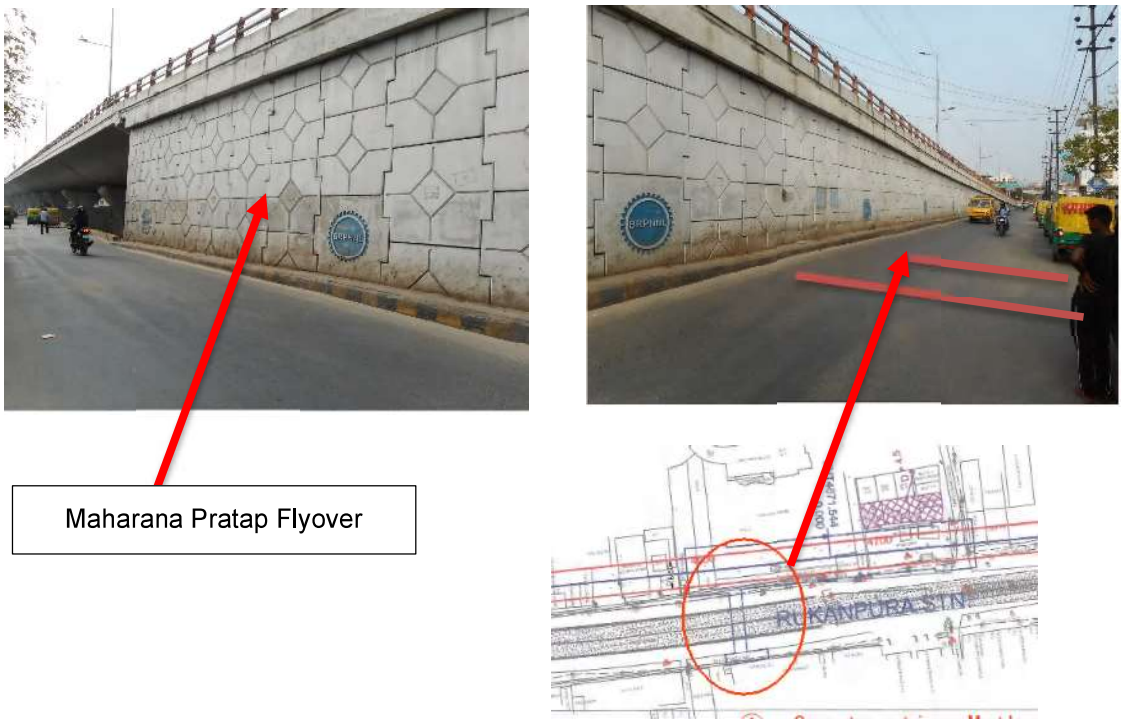



Source: PMRCL/DMRC

**Figure 5-48: As-build Drawing of Feet Road Bridge**

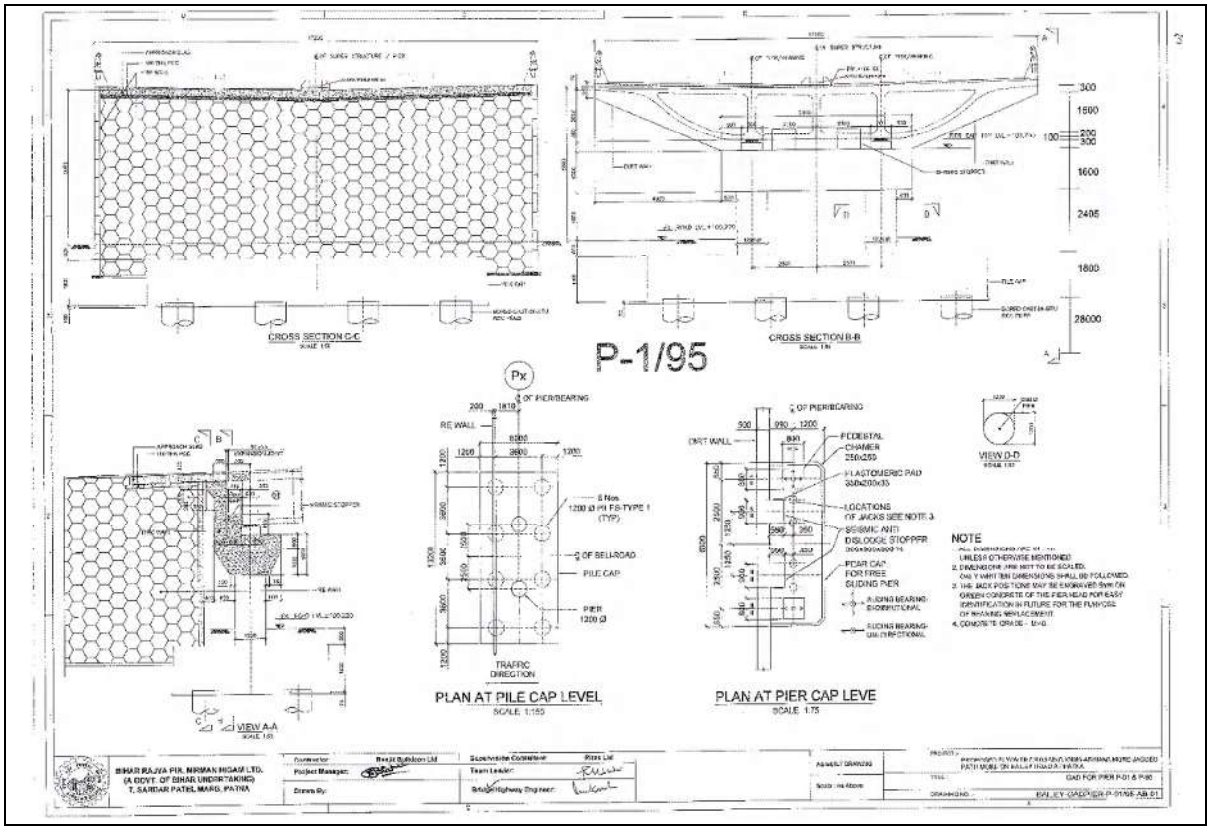
### 4) Reinforcement retaining wall embankment of Maharana Pratap Flyover

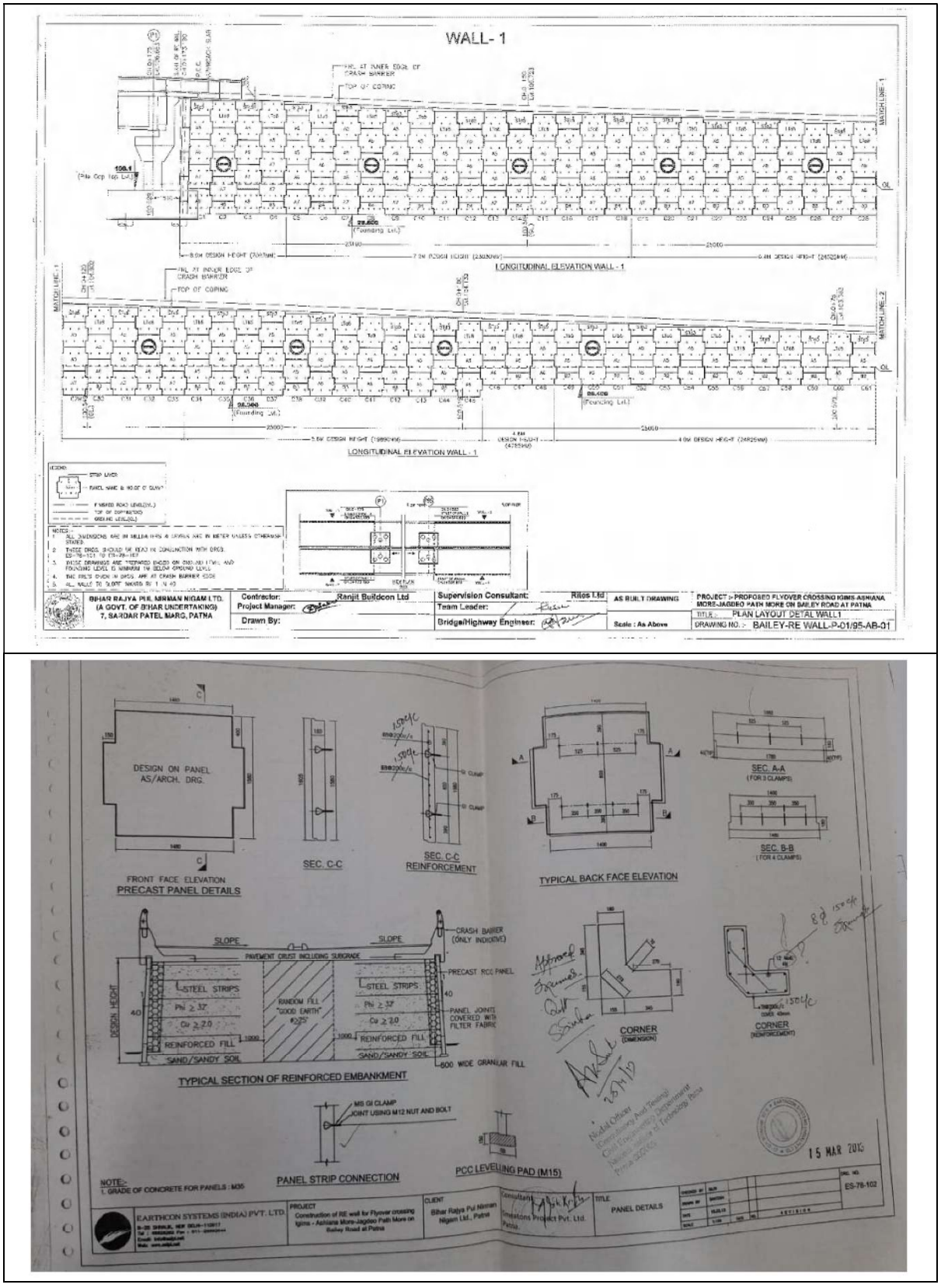
The underground entrance of Corridor1 ST05 Rukanpura is planed under the road embankment of Maharana Pratap Flyover. JST was confirmed with PMRCL/DMRC about entrance construction method.




Source: JST

**Figure 5-49: Reinforcement retaining wall embankment of Maharana Pratap Flyover**



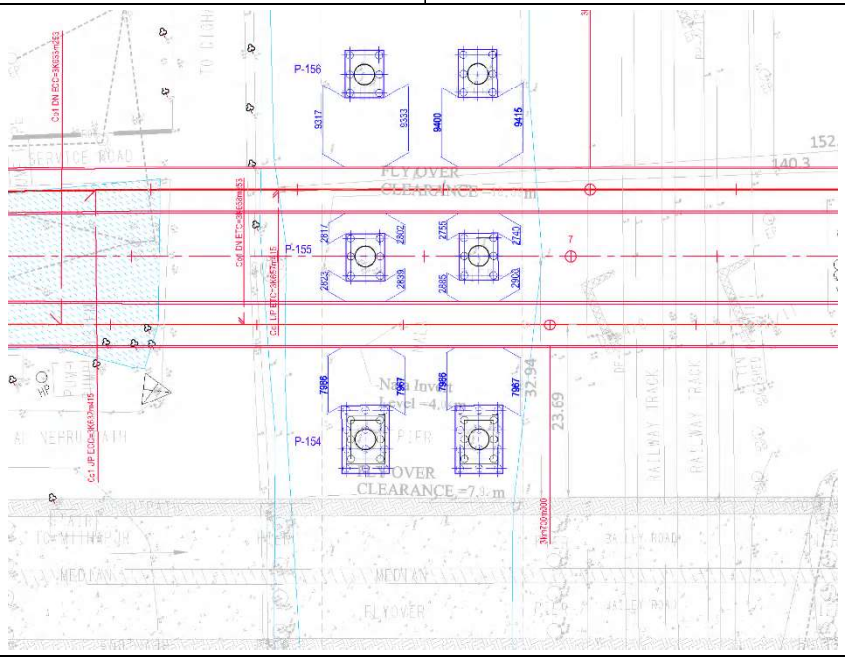
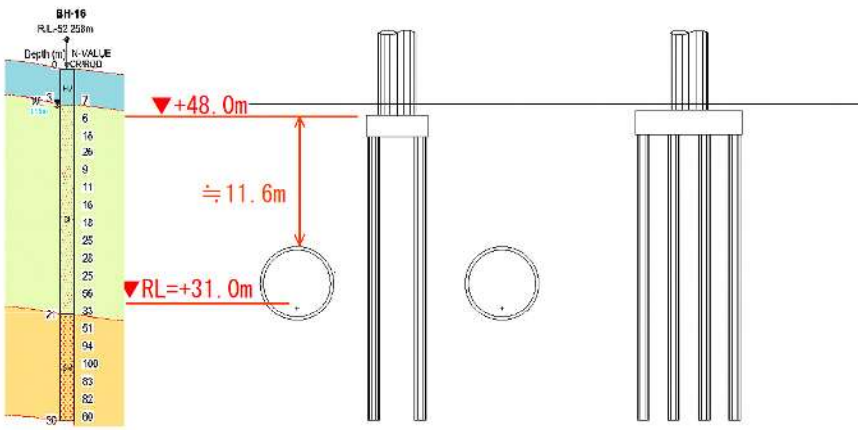


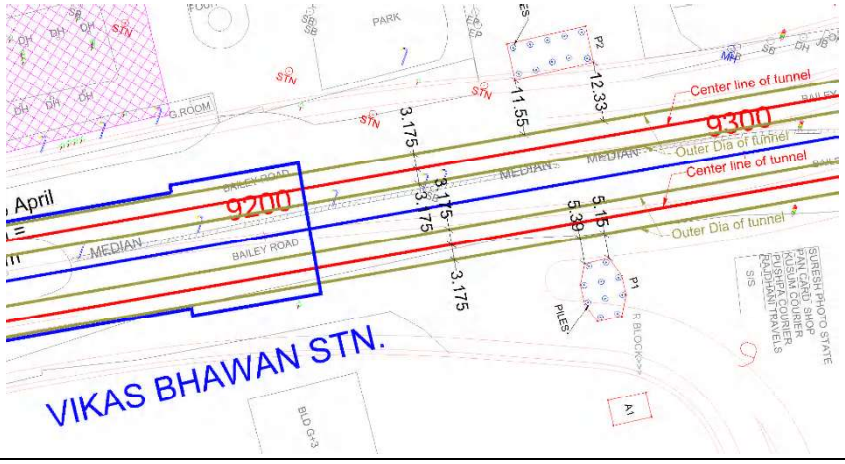
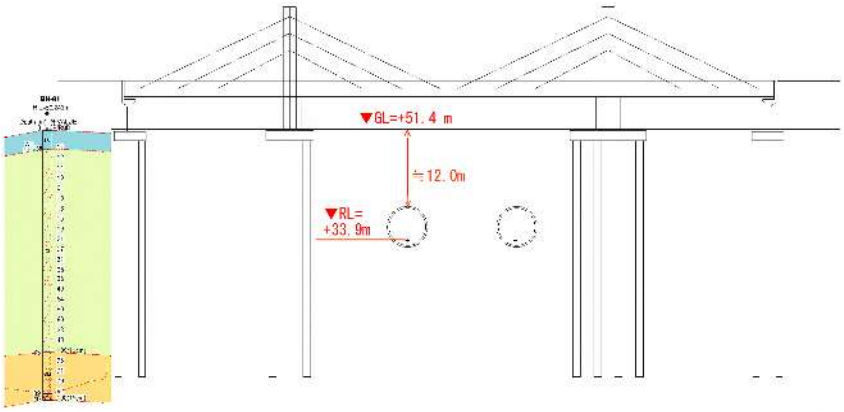

Source: PMRCL/DMRC

**Figure 5-50: As- built drawing of reinforcement retaining wall**

The below table shows the contents of the review point and the result.

**Table 5-24: The Review Result of the Existing Road Bridges during Construction**

| Existing Road Bridge | Review Contents | Review Result |
|---|---|---|
| Patna Bridge | • Location between Corridor 1 ST10 Patna Junction and pile foundation of Patna Bridge<br>• Degree of proximity both structures<br>• Space between road and soffit side of bridge for construction | • Enough distance between Corridor1 ST10 Patna Junction and pile foundation of Patna Bridge<br>• However, monitoring of bridge deformation has to be performed during station excavation stage. |
| Patriputra Bridge | • Space between TBM machine and pile foundation of the Patriputra Bridge<br>• Degree of proximity both structures | • FEM analysis for proximity pile foundation at underground TBM has to be performed in Detailed Design stage<br>• Monitoring of bridge deformation has to be performed during TBM driving |
| |  | |
| |  | |
| Feet Road | • Distance between TBM alignment and pile foundation of Feet road bridge,<br>• Degree of proximity both structures | • FEM analysis for proximity pile foundation at underground TBM has to be performed in Detailed Design stage<br>• Monitoring of bridge deformation has to be performed during TBM driving. |

| Existing Road Bridge | Review Contents | Review Result |
|---|---|---|
| | <br> | |
| Maharana Pratap Flyover (Reinforcement Embankment) | • Construction method of underground entrance of Corridor1 ST05 Rukanpura | • FEM analysis for entrance by non-digging construction under the road retaining wall has to be performed in Detailed Design stage<br>• Monitoring of deformation of existing road surface and retaining wall has to be performed during construction stage. |

Source: JST

And JST confirmed the below examination to PMRCL/DMRC.

1) How about the progress of FEM analysis and coordination meeting between PMRCL/DMRC and Road sector at the basic design stage?

2) Do you include the examination of the countermeasure method for proximity construction in the employer requirement?

The below comment is replied from PMRCL/DMRC.

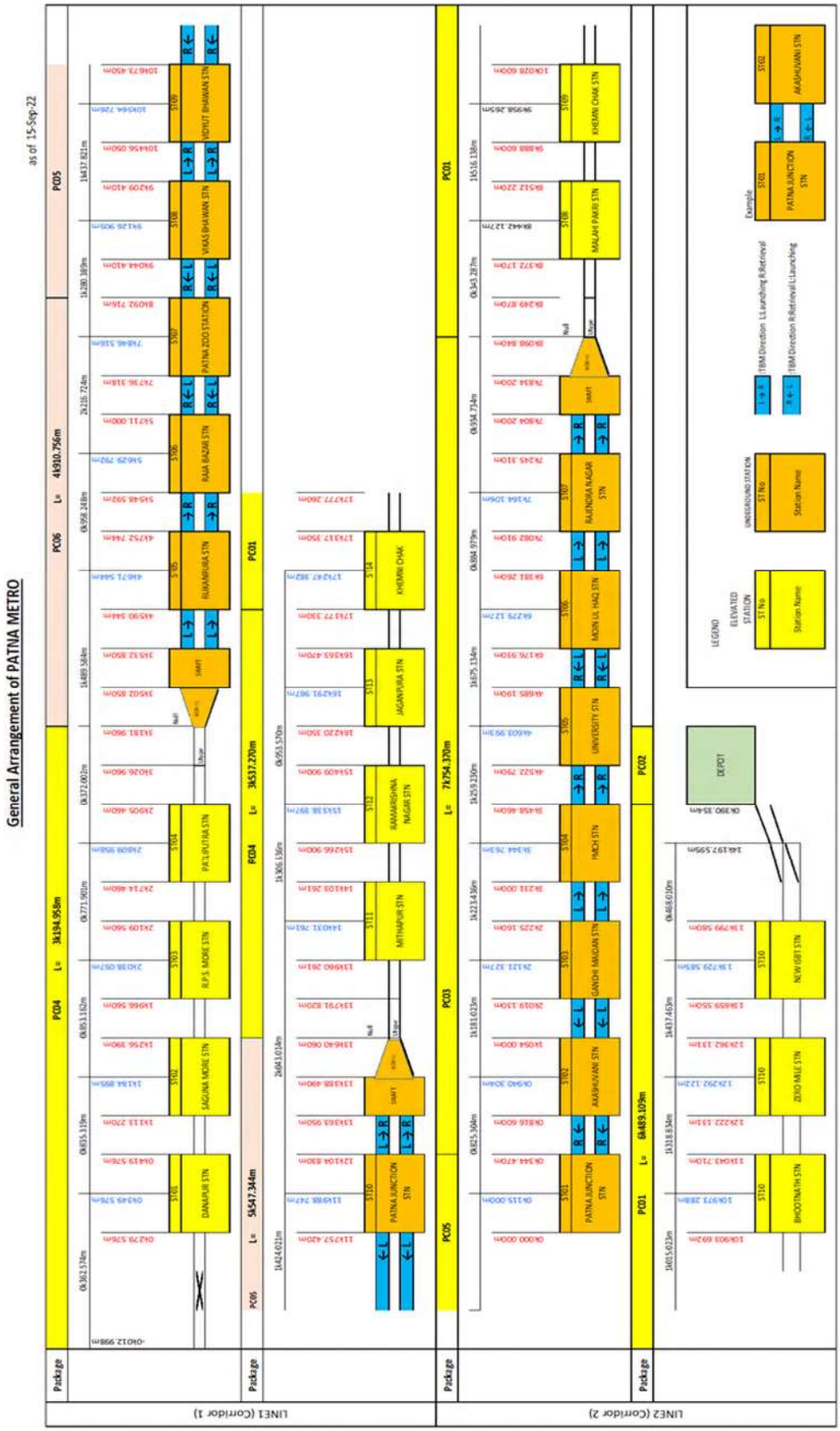
1) Being design and built contract, the required analysis and interface is done during the construction stage by the contractor and is in the scope of work of contractor.
2) Yes, the guideline for proximity construction is given in Outline Design Specification in Employer's Requirement.

## 5.4 Civil Engineering

### 5.4.1 Overview of Civil structure plan and design concept

#### (1) Civil Structure Type

The following figure shows schematic diagram of Patna Metro Rail Construction Project, which contains tentative chainage of stations given by PMRCL/DMRC.




Source: JST

**Figure 5-51: Schematic Diagram of Patna Metro (as of 15th September 2022)**

The below tables show the lengths of structure type of Corridor 1 and 2.

**Table 5-25: Structure Type of Corridor 1 (As of 15th September 2022)**

Corridor1

Unit:m

| | STATION | | Chainage | Elevated | | | Underground | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Viaduct | Station | Ramp | TBM | Station | Ramp |
| | | Start Point | -0k012.998m | | | | | | |
| | | Start of Station | 0k279.576m | 292.574 | | | | | |
| 1 | DANAPUR STN | Centre of Station | 0k349.576m | | 140.000 | | | | |
| | | End of Station | 0k419.576m | | | | | | |
| | | Start of Station | 1k113.270m | 693.694 | | | | | |
| 2 | SAGUNA MORE STN | Centre of Station | 1k184.895m | | 143.120 | | | | |
| | | End of Station | 1k256.390m | | | | | | |
| | | Start of Station | 1k966.560m | 710.170 | | | | | |
| 3 | R.P.S. MORE STN | Centre of Station | 2k038.057m | | 143.000 | | | | |
| | | End of Station | 2k109.560m | | | | | | |
| | | Start of Station | 2k714.460m | 604.900 | | | | | |
| 4 | PATLIPUTRA STN | Centre of Station | 2k809.958m | | 191.000 | | | | |
| | | End of Station | 2k905.460m | | | | | | |
| | | End of Viaduct | 3k026.960m | 121.500 | | | | | |
| | | Null Point | 3k181.960m | | | 155.000 | | | |
| | Ramp | End of U Type | 3k326.900m | | | | | | 144.940 |
| | | Start of Shaft | 3k502.850m | | | | | | 175.950 |
| | | End of Shaft | 3k532.850m | | | | | | 30.000 |
| | | Start of Station | 4k590.344m | | | | 1,057.494 | | |
| 5 | RUKANPURA STN | Centre of Station | 4k671.544m | | | | | 162.400 | |
| | | End of Station | 4k752.744m | | | | | | |
| | | Start of Station | 5k548.592m | | | | 795.848 | | |
| 6 | RAJA BAZAR STN | Centre of Station | 5k629.792m | | | | | 162.408 | |
| | | End of Station | 5k711.000m | | | | | | |
| | | Start of Station | 7k736.318m | | | | 2,025.318 | | |
| 7 | PATNA ZOO STATION | Centre of Station | 7k846.516m | | | | | 356.398 | |
| | | End of Station | 8k092.716m | | | | | | |
| | | Start of Station | 9k044.410m | | | | 951.694 | | |
| 8 | VIKAS BHAWAN STN | Centre of Station | 9k126.905m | | | | | 165.000 | |
| | | End of Station | 9k209.410m | | | | | | |
| | | Start of Station | 10k456.050m | | | | 1,246.640 | | |
| 9 | VIDYUT BHAWAN STN | Centre of Station | 10k564.726m | | | | | 217.400 | |
| | | End of Station | 10k673.450m | | | | | | |
| | | Start of Station | 11k757.420m | | | | 1,083.970 | | |
| 10 | PATNA JUNCTION STN | Centre of Station | 11k988.747m | | | | | 347.410 | |
| | | End of Station | 12k104.830m | | | | | | |
| | | Start of Shaft | 13k363.950m | | | | 1,259.120 | | |
| | | End of Shaft | 13k388.490m | | | | | | 24.540 |
| | Ramp | Start of U Type | 13k494.280m | | | | | | 105.790 |
| | | Null Point | 13k640.060m | | | | | | 145.780 |
| | | Start of Viaduct | 13k791.820m | | | 151.760 | | | |
| | | Start of Station | 13k960.261m | 168.441 | | | | | |
| 11 | MITHAPUR STN | Centre of Station | 14k031.761m | | 143.000 | | | | |
| | | End of Station | 14k103.261m | | | | | | |
| | | Start of Station | 15k266.900m | 1,163.639 | | | | | |
| 12 | RAMAKRISHNA NAGAR STN | Centre of Station | 15k338.397m | | 143.000 | | | | |
| | | End of Station | 15k409.900m | | | | | | |
| | | Start of Station | 16k220.350m | 810.450 | | | | | |
| 13 | JAGANPURA STN | Centre of Station | 16k291.967m | | 143.120 | | | | |
| | | End of Station | 16k363.470m | | | | | | |
| | | Start of Station | 17k177.330m | 813.860 | | | | | |
| 14 | KHEMNI CHAK | Centre of Station | 17k247.382m | | 140.020 | | | | |
| | | End of Station | 17k317.350m | | | | | | |
| | | End Point | 17k777.260m | 459.910 | | | | | |
| | Sub Total | | | 5,839.138 | 1,186.260 | 306.760 | 8,420.084 | 1,411.016 | 627.000 |
| | | | | | 7,332.158 | | | 10,458.100 | |
| | Total | | | 17,790.258 | | | | | |

Source: JST

**Table 5-26: Structure Type of Corridor 2 (As of 15th September 2022)**

Corridor2

Unit:m

| | STATION | | Chainage | Elevated | | | Underground | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Viaduct | Station | Ramp | TBM | Station | Ramp |
| | | Start of Station | 0k000.000m | | | | | | |
| | PATNA JUNCTION STN | Centre of Station | 0k115.000m | | | | | 344.470 | |
| | | End of Station | 0k344.470m | | | | | | |
| | | Start of Station | 0k816.600m | | | | 472.130 | | |
| 1 | AKASHUVANI STN | Centre of Station | 0k940.304m | | | | | 237.400 | |
| | | End of Station | 1k054.000m | | | | | | |
| | | Start of Station | 2k019.130m | | | | 965.130 | | |
| 2 | GANDHI MAIDAN STN | Centre of Station | 2k121.327m | | | | | 206.030 | |
| | | End of Station | 2k225.160m | | | | | | |
| | | Start of Station | 3k231.000m | | | | 1,005.840 | | |
| 3 | PMCH STN | Centre of Station | 3k344.763m | | | | | 227.460 | |
| | | End of Station | 3k458.460m | | | | | | |
| | | Start of Station | 4k522.790m | | | | 1,064.330 | | |
| 4 | UNIVERSITY STN | Centre of Station | 4k603.993m | | | | | 162.400 | |
| | | End of Station | 4k685.190m | | | | | | |
| | | Start of Station | 6k176.930m | | | | 1,491.740 | | |
| 5 | MOIN UL HAQ STN | Centre of Station | 6k279.127m | | | | | 204.330 | |
| | | End of Station | 6k381.260m | | | | | | |
| | | Start of Station | 7k082.910m | | | | 701.650 | | |
| 6 | RAJENDRA NAGAR STN | Centre of Station | 7k164.106m | | | | | 162.400 | |
| | | End of Station | 7k245.310m | | | | | | |
| | | Start of Shaft | 7k804.200m | | | | 558.890 | | |
| | | End of Shaft | 7k834.200m | | | | | | 30.000 |
| | Ramp | Start of U Type | 7k949.870m | | | | | | 115.670 |
| | | Null Point | 8k098.840m | | | | | | 148.970 |
| | | Start of Viaduct | 8k249.870m | | | 151.030 | | | |
| | | Start of Station | 8k372.170m | 122.300 | | | | | |
| 1 | MALAHI PAKRI STN | Centre of Station | 8k442.127m | | 140.050 | | | | |
| | | End of Station | 8k512.220m | | | | | | |
| | | Start of Station | 9k888.600m | 1,376.380 | | | | | |
| 2 | KHEMNI CHAK STN | Centre of Station | 9k958.265m | | 140.000 | | | | |
| | | End of Station | 10k028.600m | | | | | | |
| | | Start of Station | 10k903.692m | 875.092 | | | | | |
| 3 | BHOOTNATH STN | Centre of Station | 10k974.288m | | 140.018 | | | | |
| | | End of Station | 11k043.710m | | | | | | |
| | | Start of Station | 12k222.131m | 1,178.421 | | | | | |
| 4 | ZERO MILE STN | Centre of Station | 12k292.122m | | 140.000 | | | | |
| | | End of Station | 12k362.131m | | | | | | |
| | | Start of Station | 13k659.550m | 1,297.419 | | | | | |
| 5 | NEW ISBT STN | Centre of Station | 13k729.585m | | 140.030 | | | | |
| | | End of Station | 13k799.580m | | | | | | |
| | | End Point | 14k197.595m | 398.015 | | | | | |
| | Sub Total | | | 5,247.627 | 700.098 | 151.030 | 6,259.710 | 1,544.490 | 294.640 |
| | | | | 6,098.755 | | | 8,098.840 | | |
| | Total | | | 14,197.595 | | | | | |

| STATION | | Chainage | Elevated | | | Underground | | |
|---|---|---|---|---|---|---|---|---|
| | | | Viaduct | Station | Ramp | TBM | Station | Ramp |
| Depot Line | Start of Depot Line | 0k000.000m | | | | | | |
| | End of Viaduct | 0k231.130m | 231.130 | | | | | |
| | End t of Depot Line | 0k390.354m | | | 159.224 | | | |
| Sub Total | | | 231.130 | 0.000 | 159.224 | 0.000 | 0.000 | 0.000 |

Corridor2

| Structure Type | Elevated | | | Underground | | |
|---|---|---|---|---|---|---|
| | Viaduct | Station | Ramp | TBM | Station | Ramp |
| Sub Total | 5,478.757 | 700.098 | 310.254 | 6,259.710 | 1,544.490 | 294.640 |
| | 6,489.109 | | | 8,098.840 | | |
| Total | 14,587.949 | | | | | |

Source: JST

## (2) Design

Detailed design of civil structure will be carried out by the Contractor following FIDIC Yellow Design and Build which was applied to Delhi Metro Phase 1, 2, 3 and 4 project. Also specification for Patna Metro civil design refers to Delhi Metro Project Phase 4. The below figure shows the table of contents of specification for Patna Metro civil design.



OUTLINE DESIGN SPECIFICATIONS
FOR
PHASE - I OF PATNA MRTS PROJECT
(FEB 2020)

DELHI METRO RAIL CORPORATION LTD.
Metro Bhawan, Fire Brigade Lane,
Barakhamba Road, New Delhi

Table of Contents

| S.No. | Description | Page No. |
|---|---|---|
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| 2 | Outline Design Specifications for Viaduct | 3 |
| 3 | Outline Design Specifications for Double Decker Structure | 31 |
| 4 | Outline Design Specifications for Elevated Stations | 39 |
| 5 | Outline Design Specifications for Cut & Cover Section | 56 |
| 6 | Outline Design Specifications for Bored Tunnel | 95 |
| 7 | Outline Design Criteria for Geotechnical Works | 118 |
| 8 | List of Design Codes and Standards | 126 |

Source: PMRC/DMRC

**Figure 5-52: Civil Design Specification for Patna Metro Rail Construction Project**

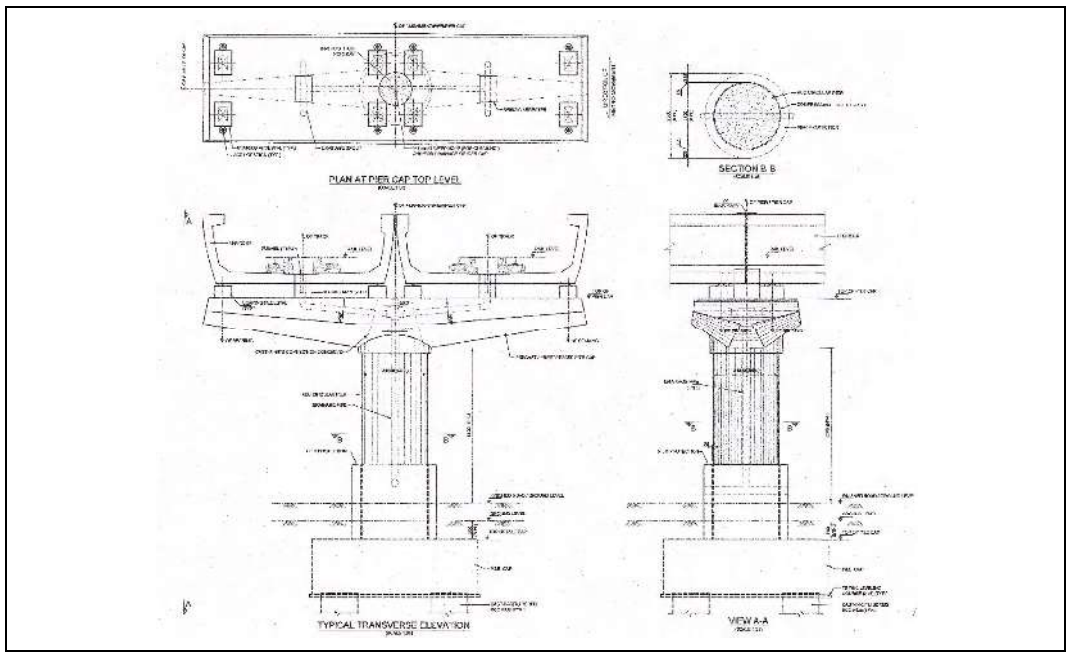
### (3) Elevated Section

The viaduct alignment of Corridor 1 is planned along the center of existing roads, but part of the section is planned at beside of existing road to fit for underground alignment. The viaduct alignment of the Corridor 2 is also planned along the center of existing road, but section of National Highway 31 is planned at beside of the existing road.

The soffit side of the viaducts has a vertical clearance of a minimum of 5.5 m above road level. The viaduct structure types are U-shape and I-Shape pre-stressed concrete bridge for typical section and steel truss arch girder for long span bridges whose types were adopted the Delhi Metro Project.

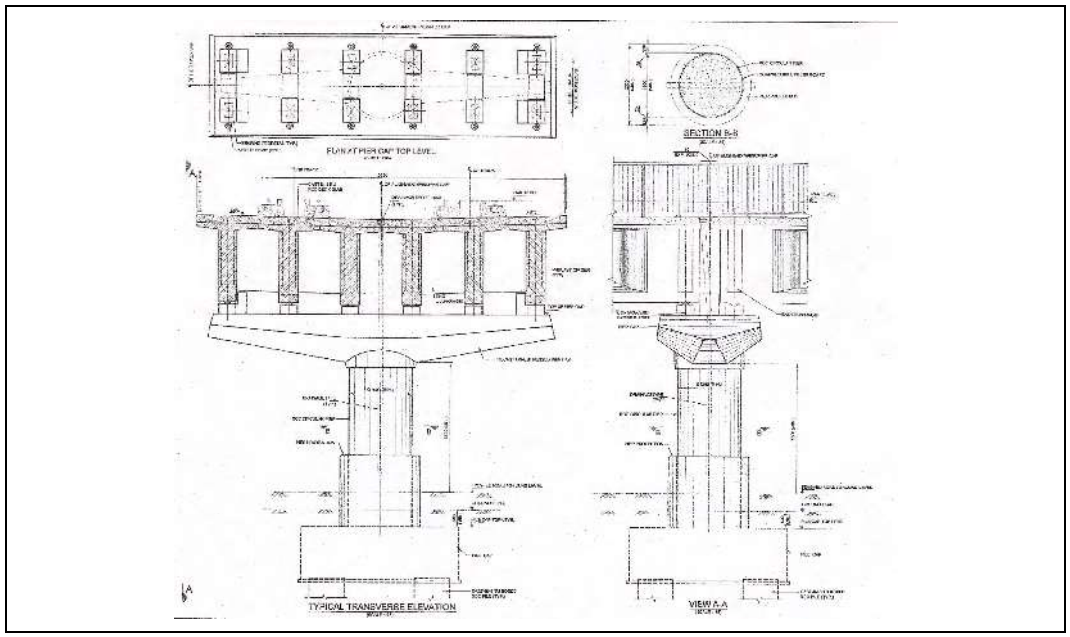
The station located above the central median is 2 (two) stories structure and the viaduct section of Corridor 1 and the Corridor 2 were awarded and part of viaduct section are currently under execution. U-shape PC girder and pier column head are fabricated at the Corridor 2 casting yard.

The general drawings of the viaduct for Corridor1 and 2 are shown below figures.



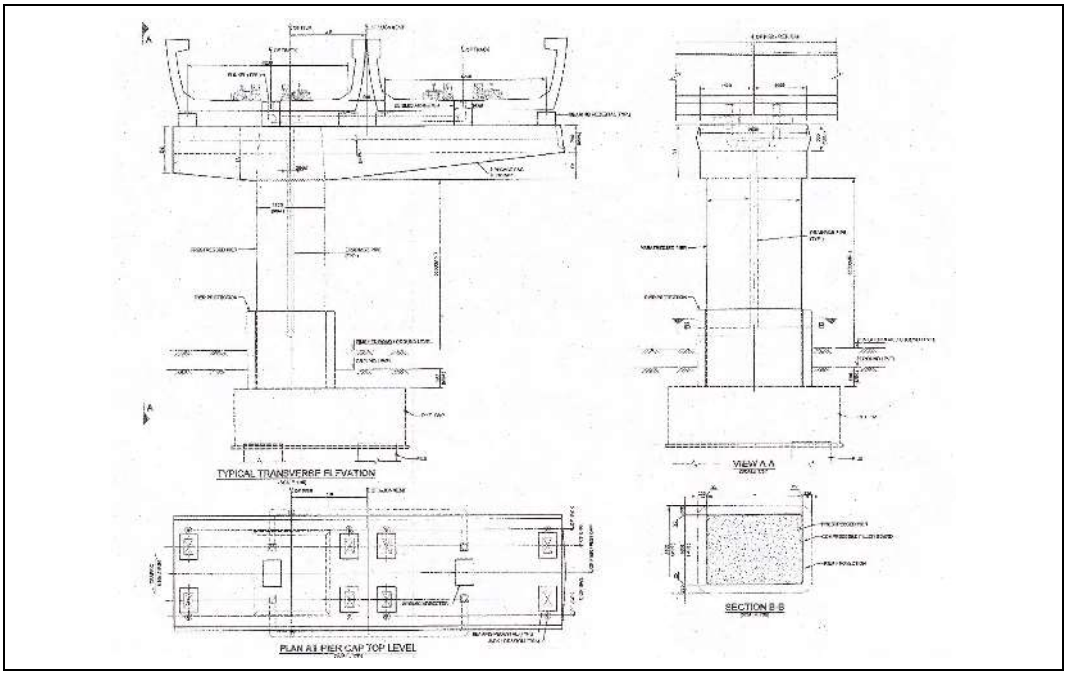

Source: PMRCL/DMRC

**Figure 5-53: Typical Structure Type of Viaduct and Pier (1)**



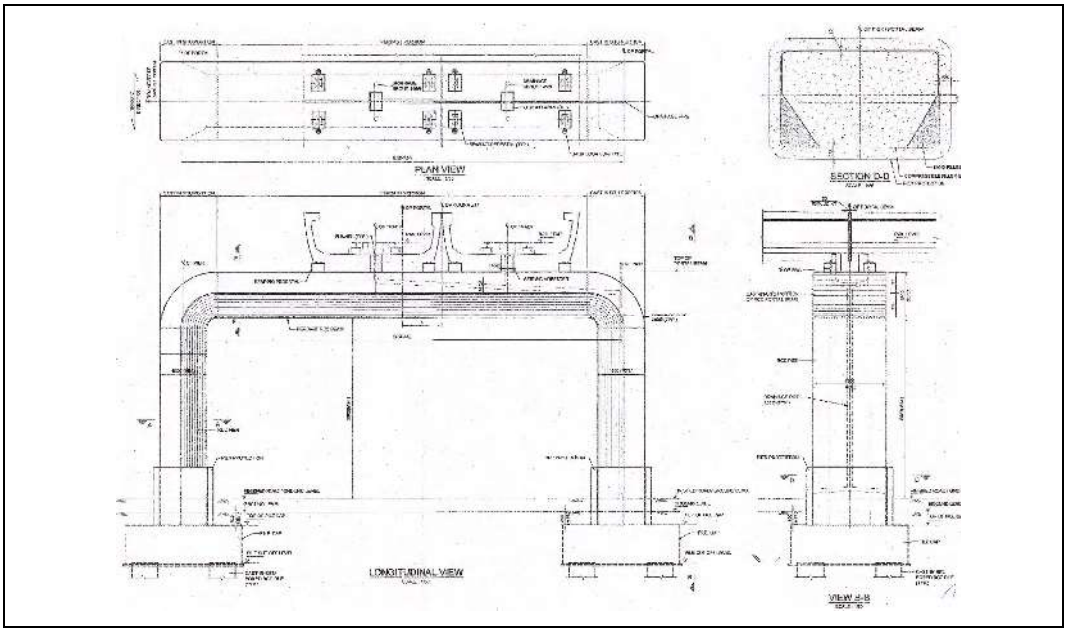

Source: PMRCL/DMRC

**Figure 5-54: Typical Structure Type of Viaduct and Pier (2)**



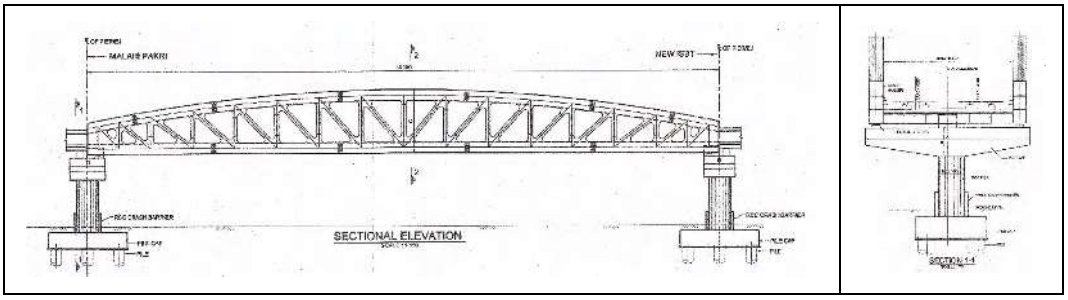

Source: PMRCL/DMRC

**Figure 5-55: Structure Type of Viaduct and Pier (3)**



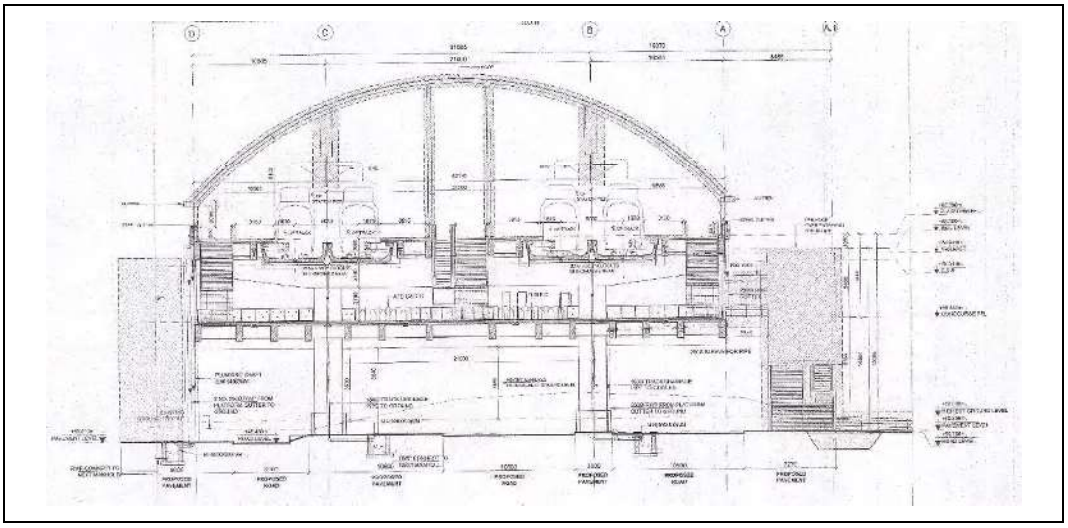

Source: PMRCL/DMRC

**Figure 5-56: Structure Type of Viaduct and Pier (4)**



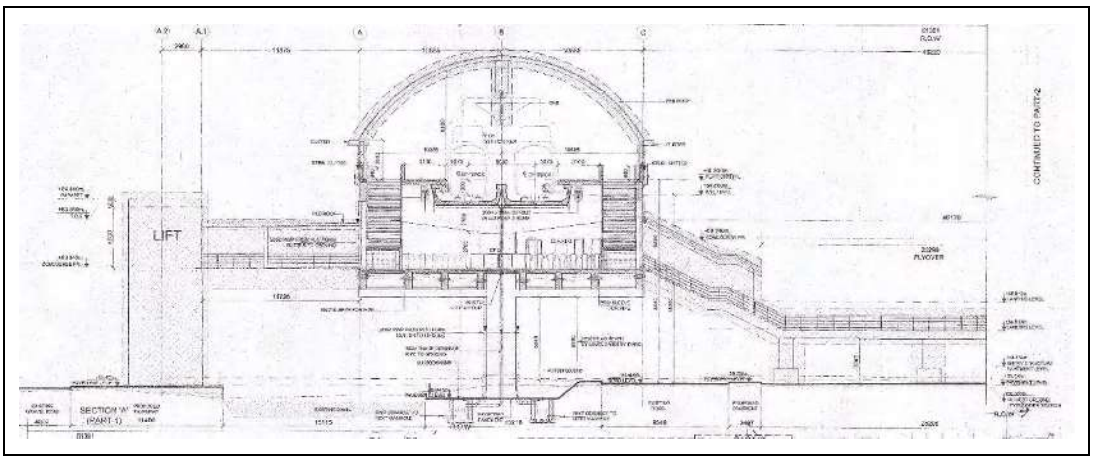

Source: PMRCL/DMRC

**Figure 5-57: Structure Type of Viaduct (Truss Bridge) and Pier**



Source: PMRCL/DMRC

**Figure 5-58: Corrido2 ST09 Khemni Chak**




Source: PMRCL/DMRC

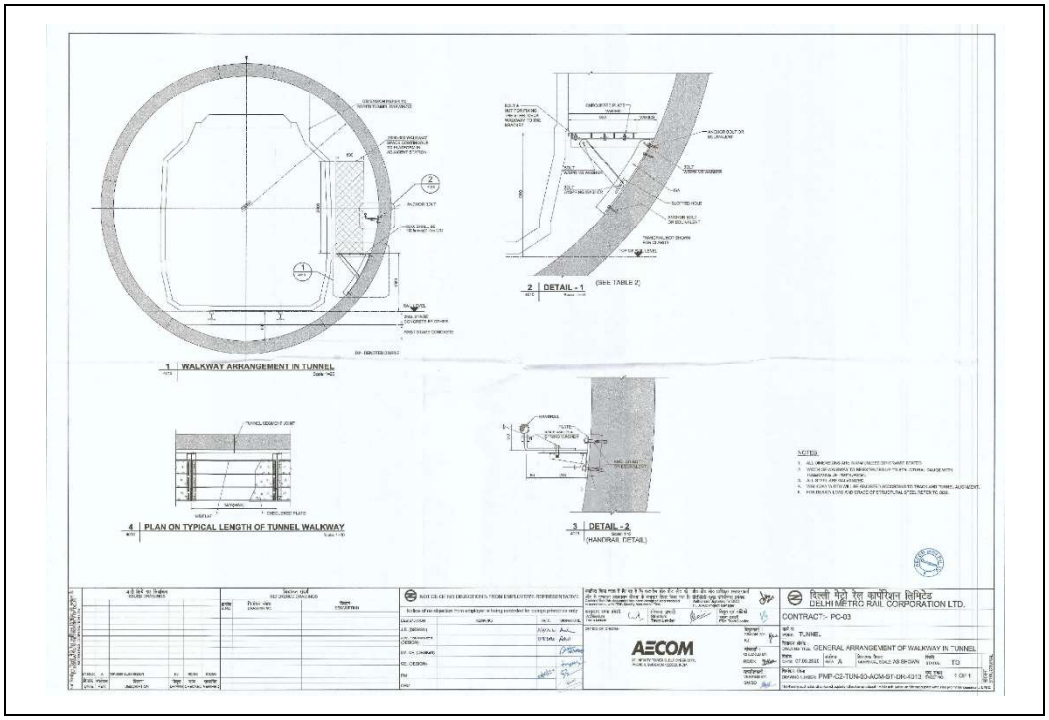
**Figure 5-59: Corridor 2 ST11 Zero Mile**

### (4) Underground Section

Construction methods of underground section are:

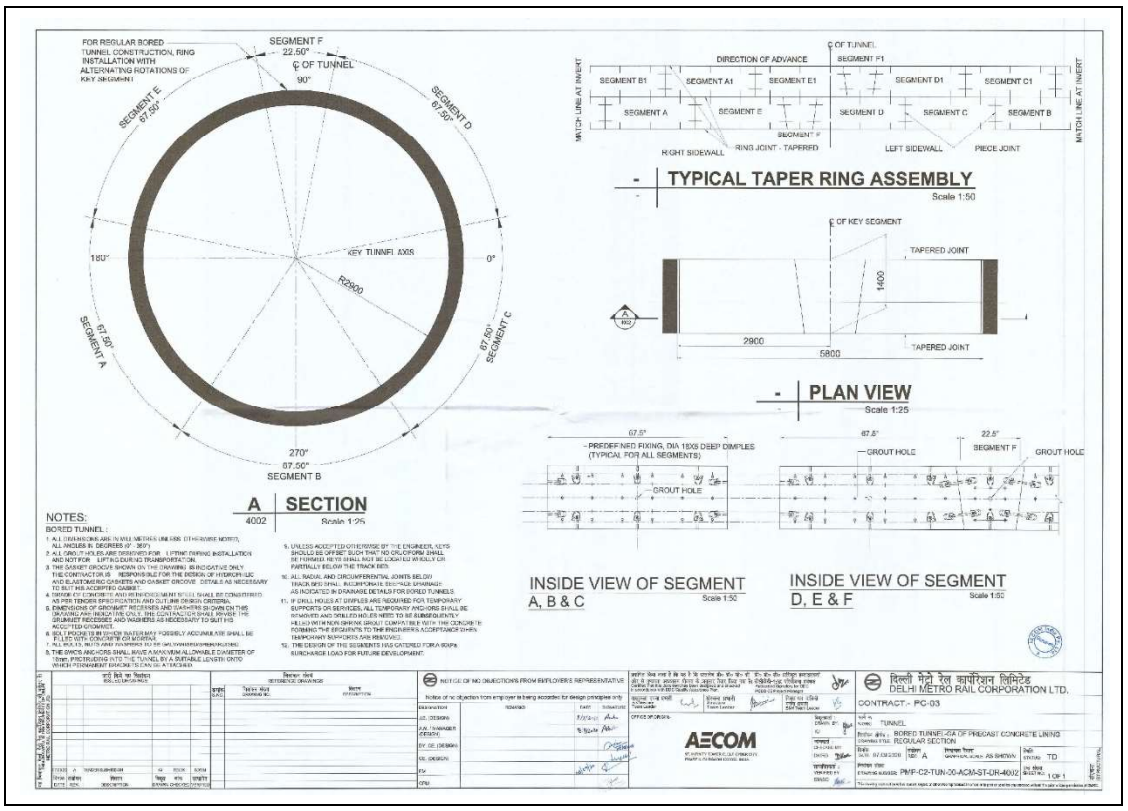
**Between stations and shaft:**

- Single track TBM (Tunnel Boring Machine)
- TBM external diameter is Φ6.35m




Source: PMRCL/DMRC

**Figure 5-60: General Arrangement Walkway in Tunnel**




Source: PMRCL/DMRC

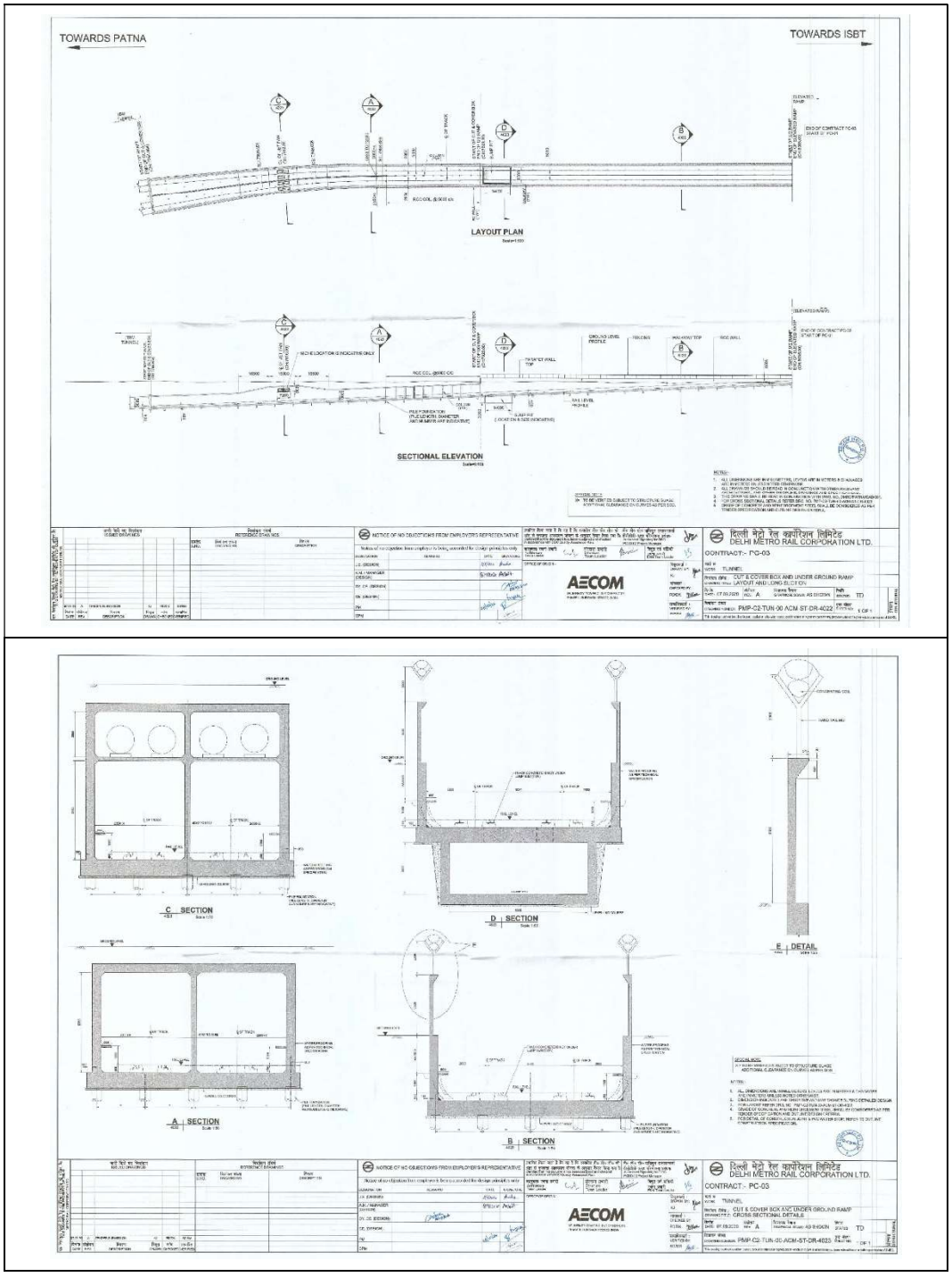
**Figure 5-61: Bored Tunnel General Arrangement of Precast Concrete Lining Regular Section**

**Station:**

- Cut and cover method with diaphragm wall (D/Wall). D/Wall is permanent structure of side wall of station.

**Ramp and shaft:**

- Cut and cover method

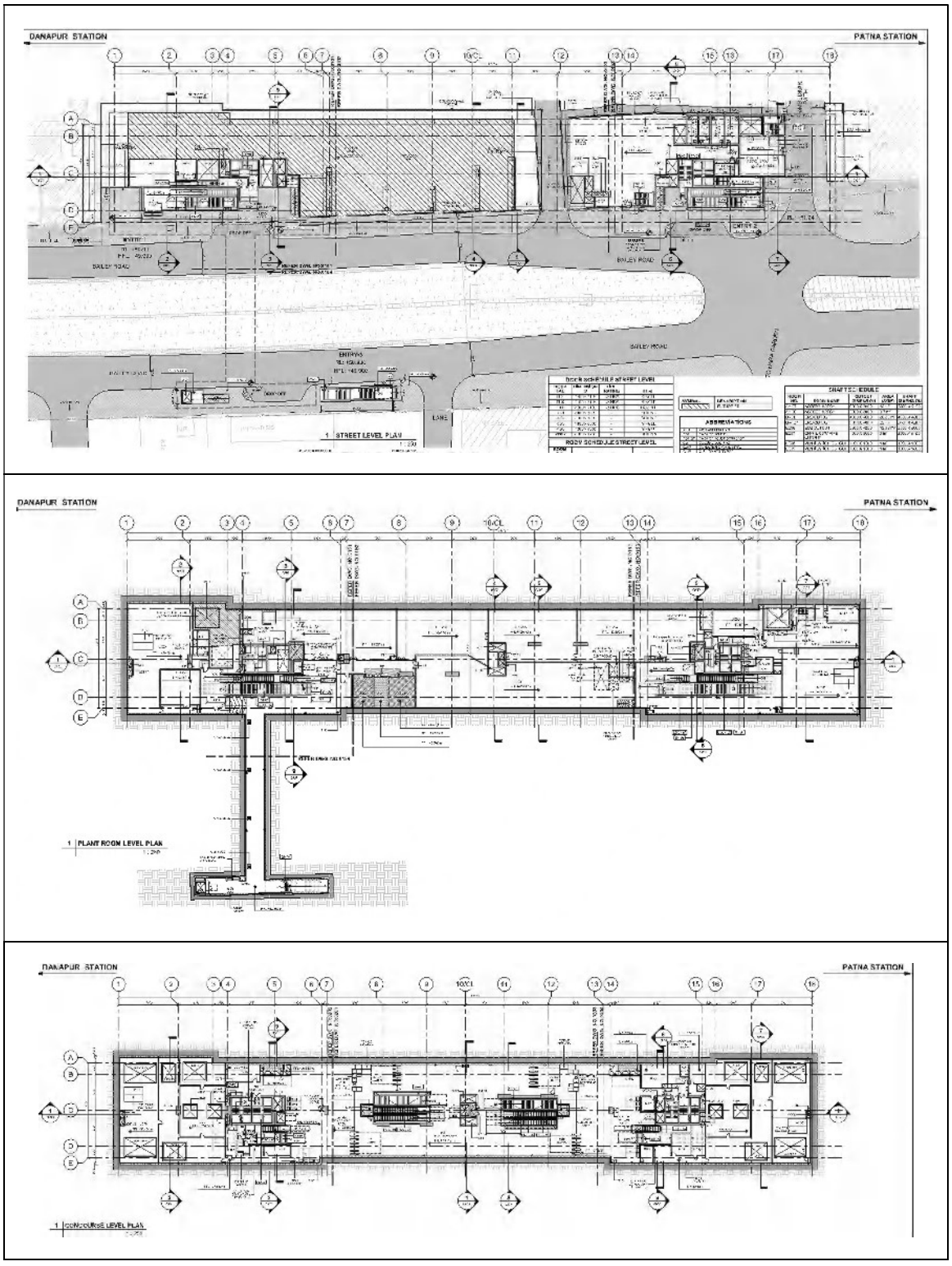


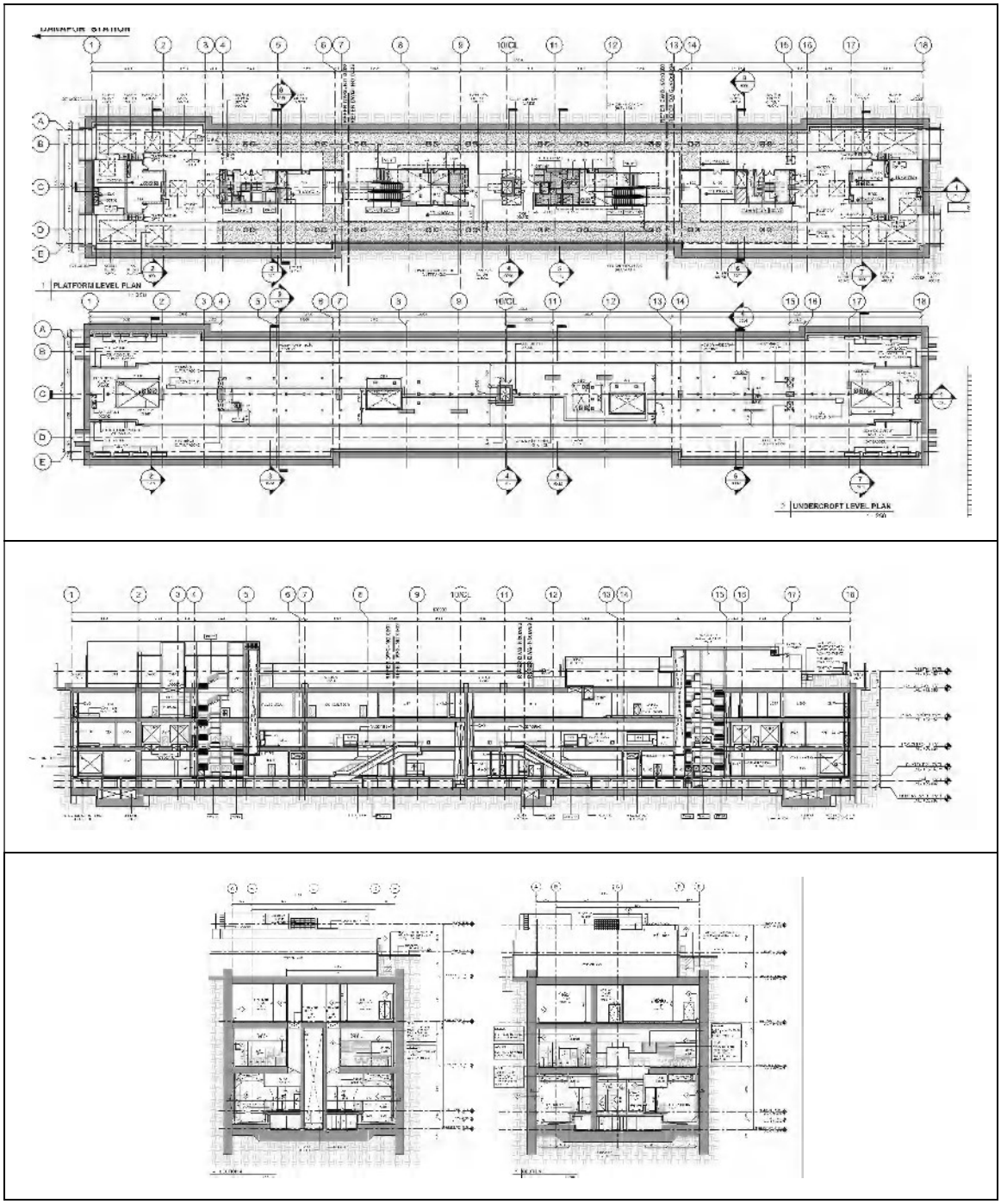

Source: PMRCL/DMRC

**Figure 5-62: Cut & Cover Box and Under Ground Ramp**

JST received tender drawing of the Corridor 2, and basic design drawing of Corridor 1.

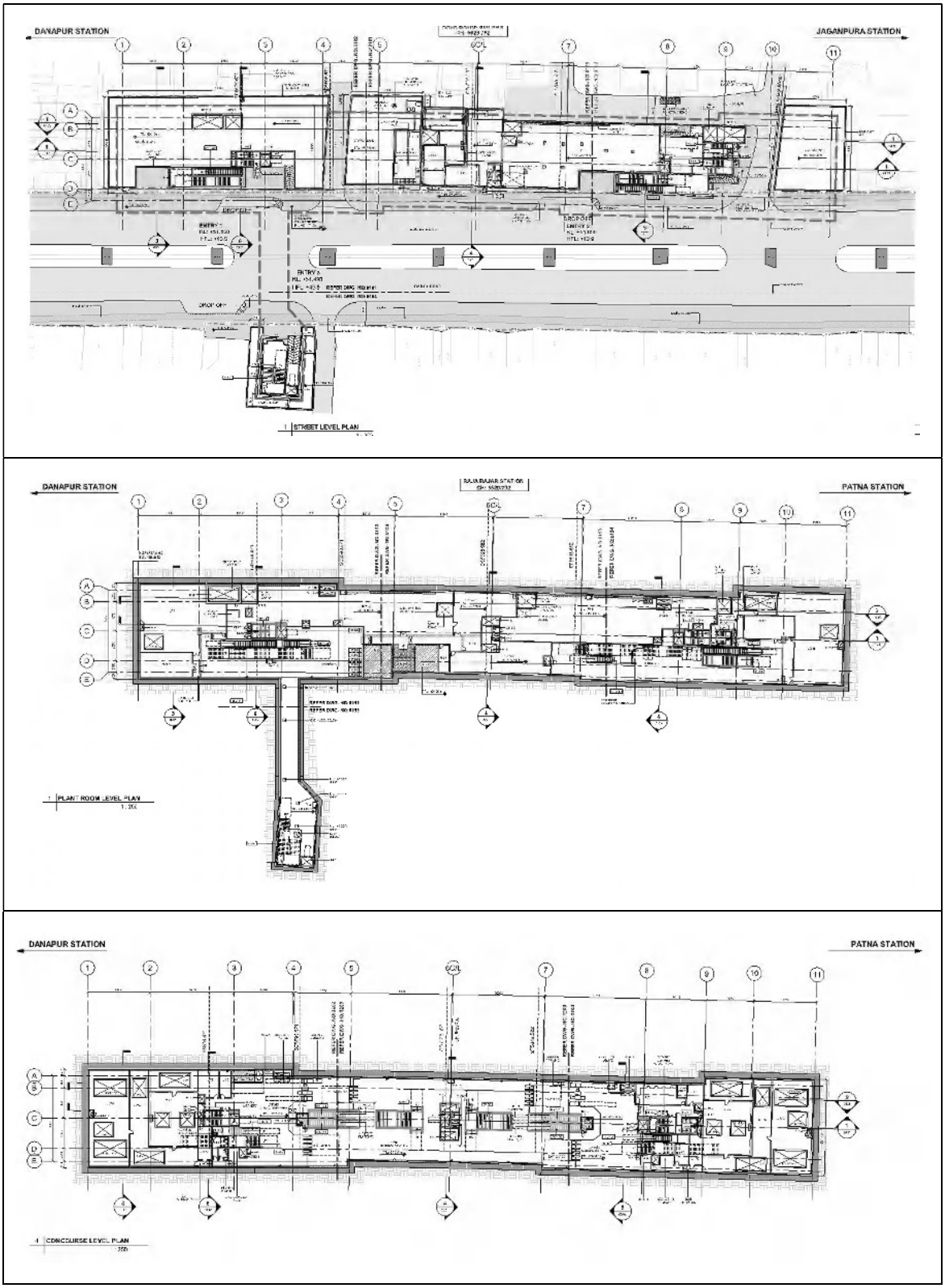
The below figures show the general drawings of underground station of Corridor1.

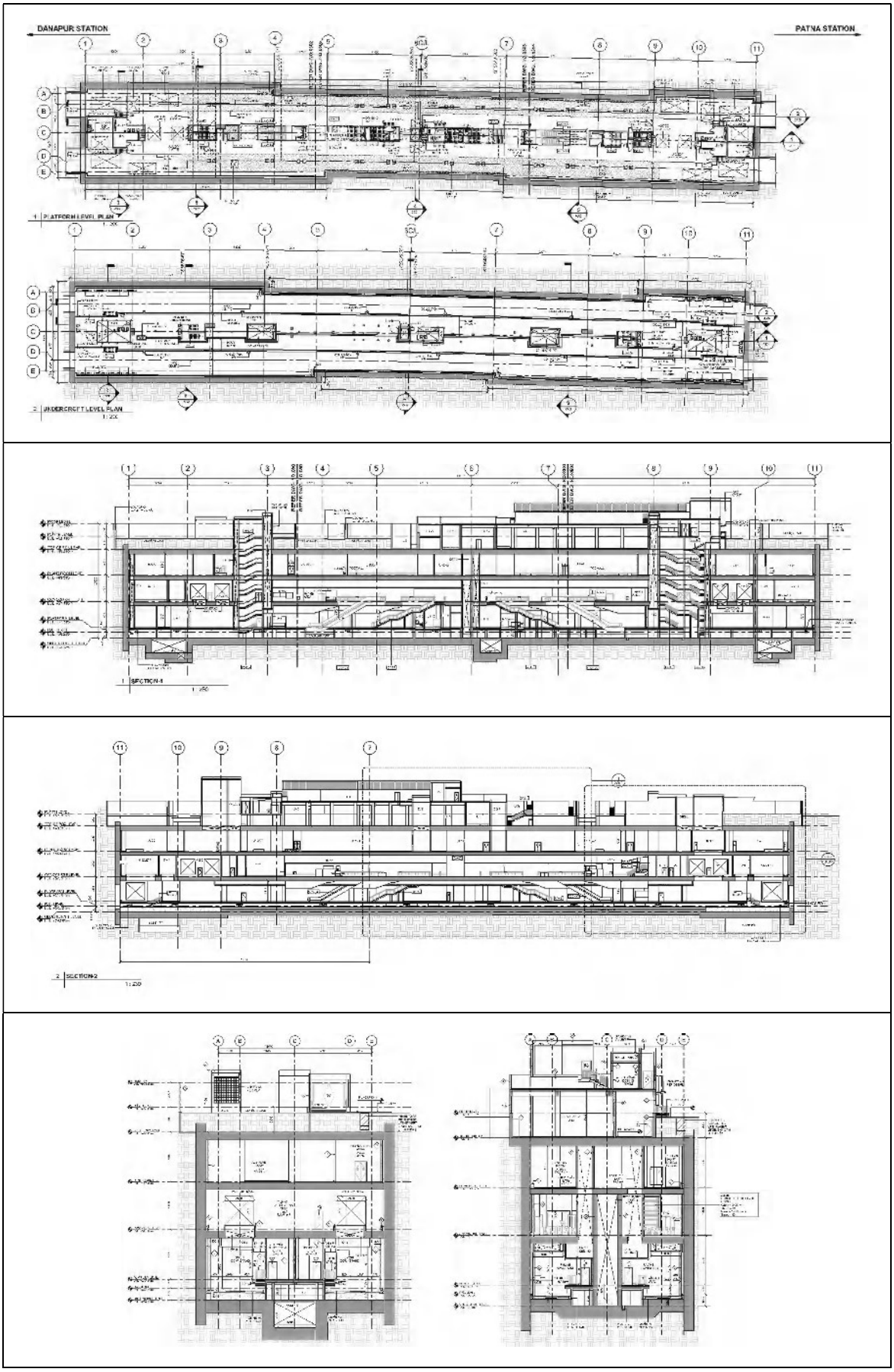





Source: PMRCL/DMRC

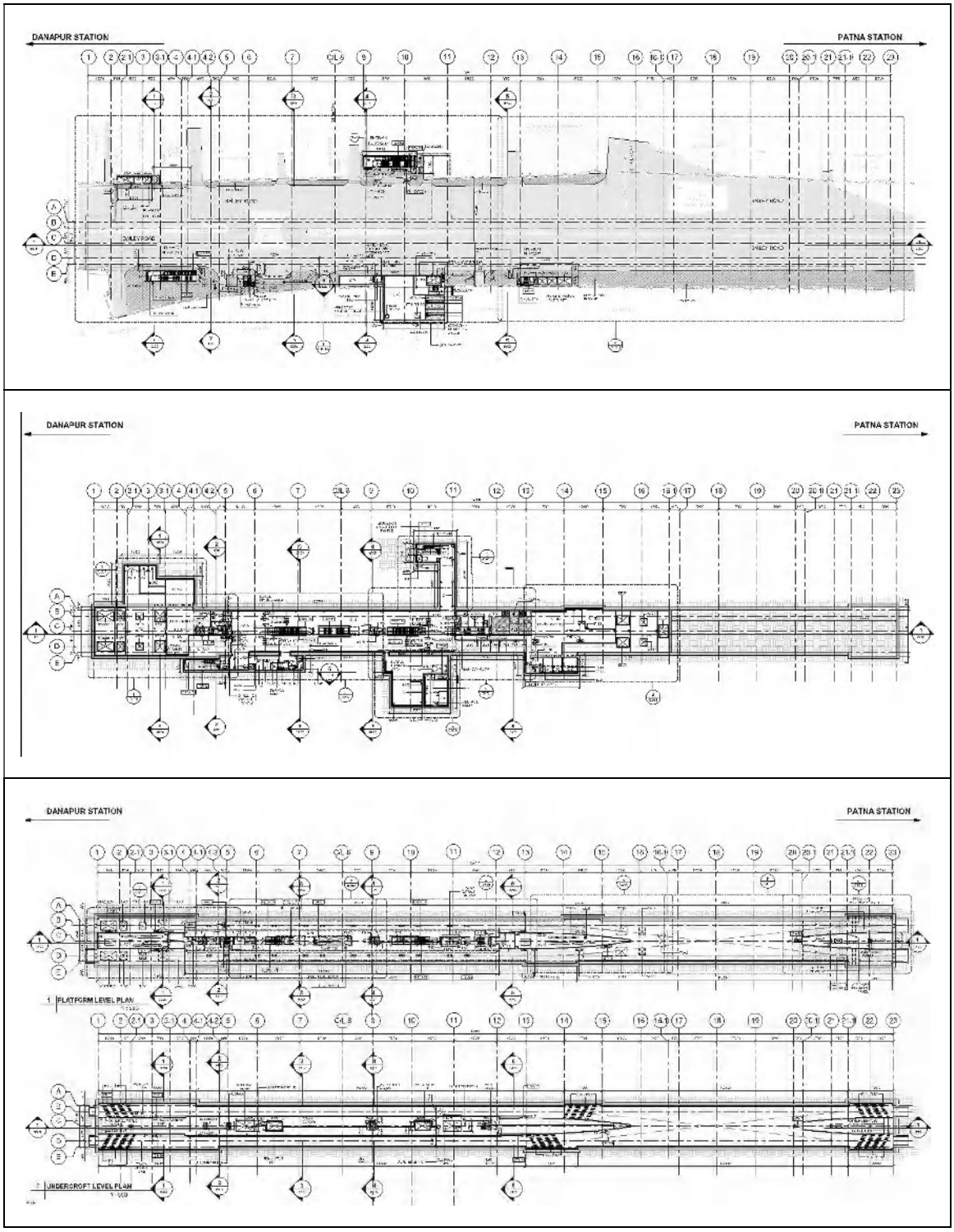
**Figure 5-63: Corridor1 ST05 Rukanpura**

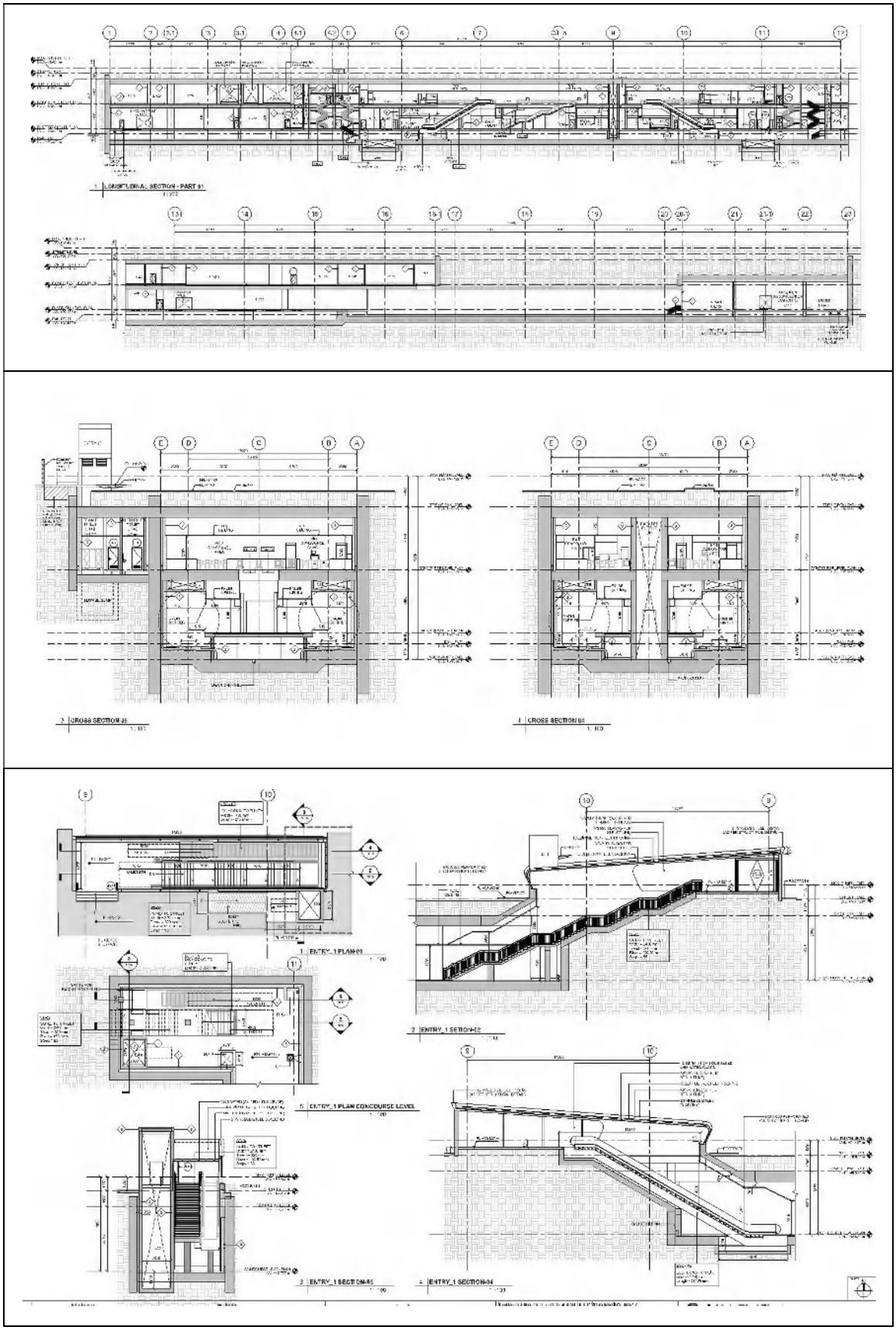

DANAPUR STATION
JAGANPURA STATION
1 STREET LEVEL PLAN
DANAPUR STATION
PATNA STATION
1 PLANT ROOM LEVEL PLAN
DANAPUR STATION
PATNA STATION
1 CONCOURSE LEVEL PLAN




Source: PMRCL/DMRC

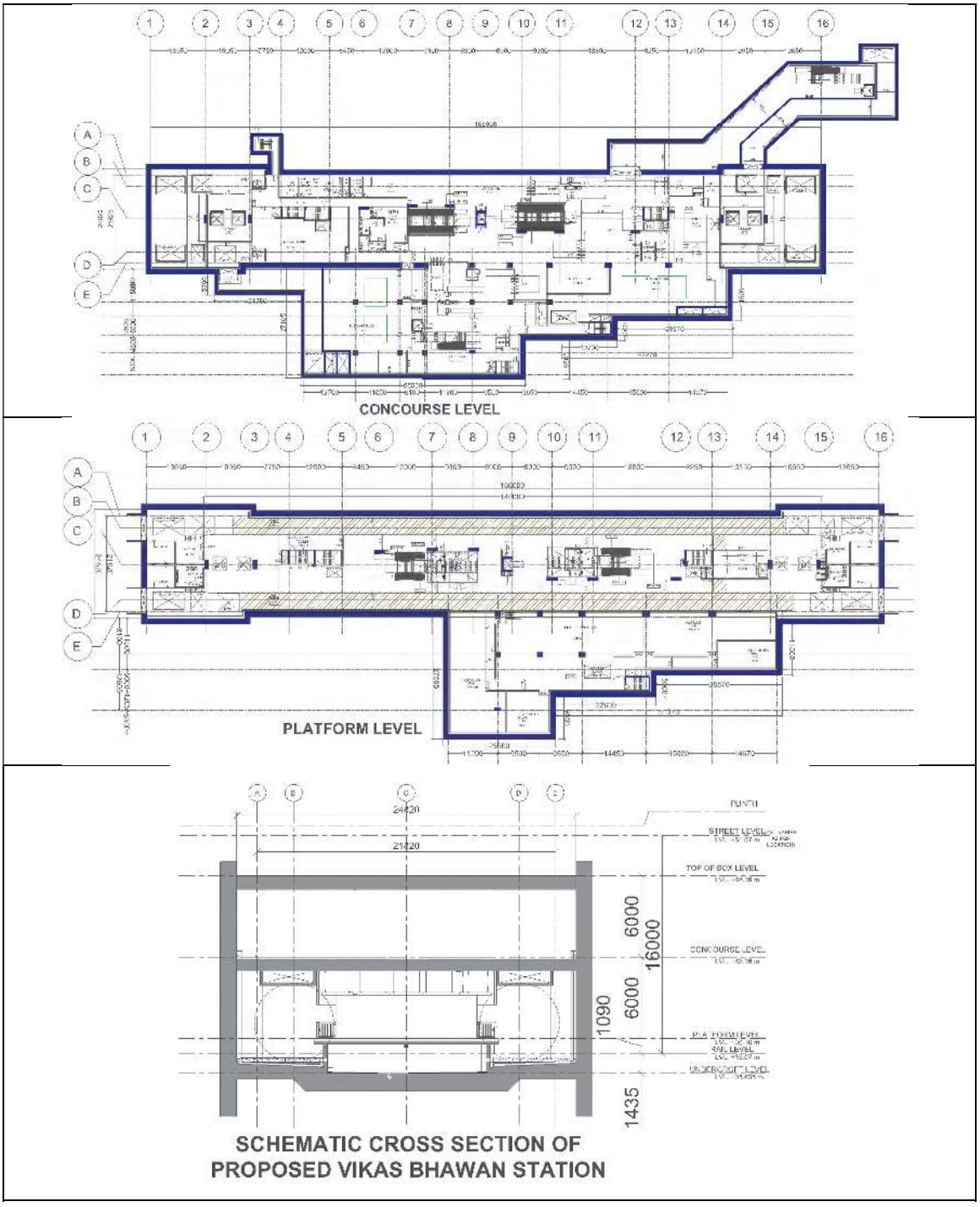
**Figure 5-64: Corridor1 ST06 Raja Bazar**


DANAPUR STATION
PATNA STATION
DANAPUR STATION
PATNA STATION
DANAPUR STATION
PATNA STATION
1 PLATFORM LEVEL PLAN
2 UNDERCROFT LEVEL PLAN



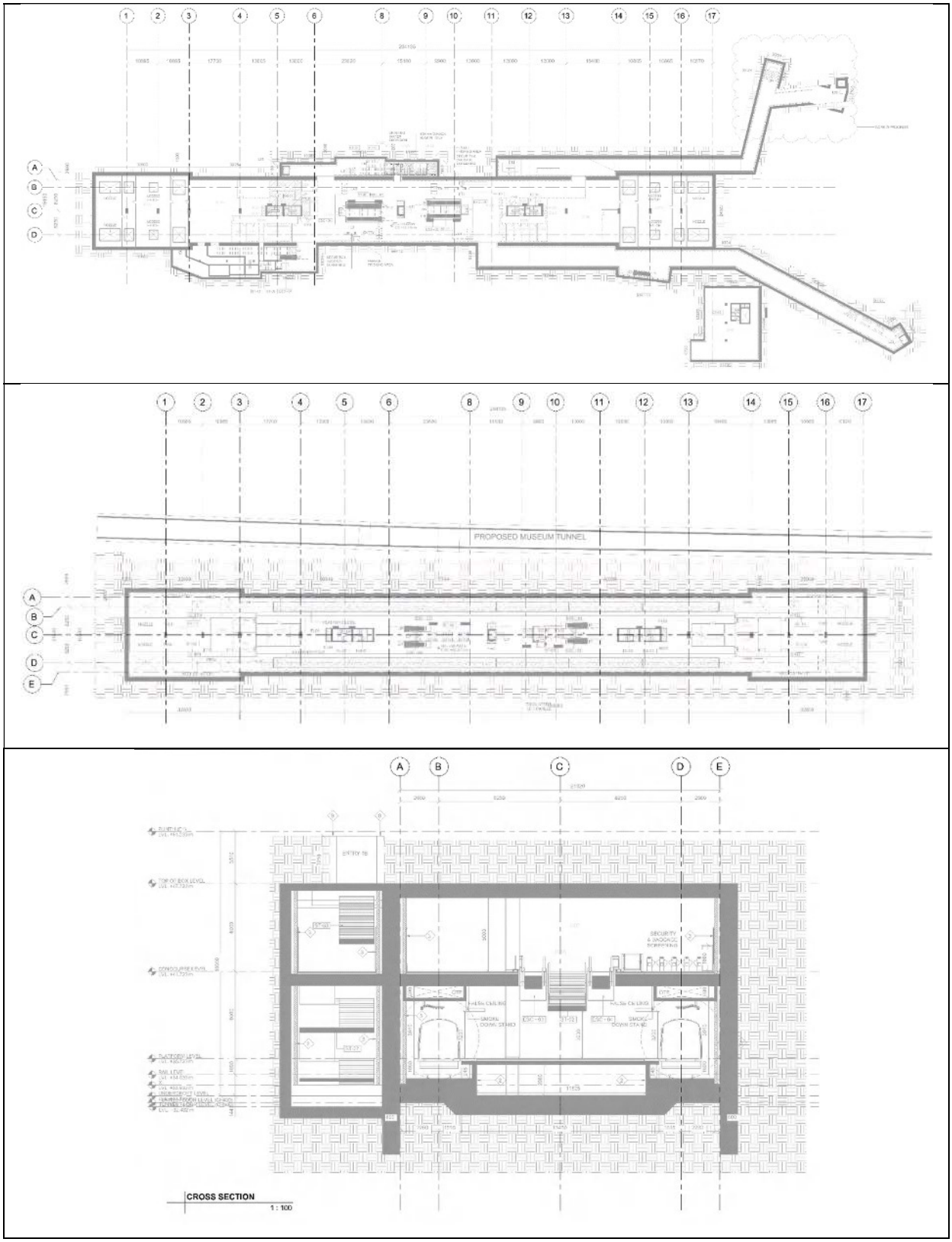
Source: PMRCL/DMRC

**Figure 5-65: Corridor1 ST07 Patna Zoo**



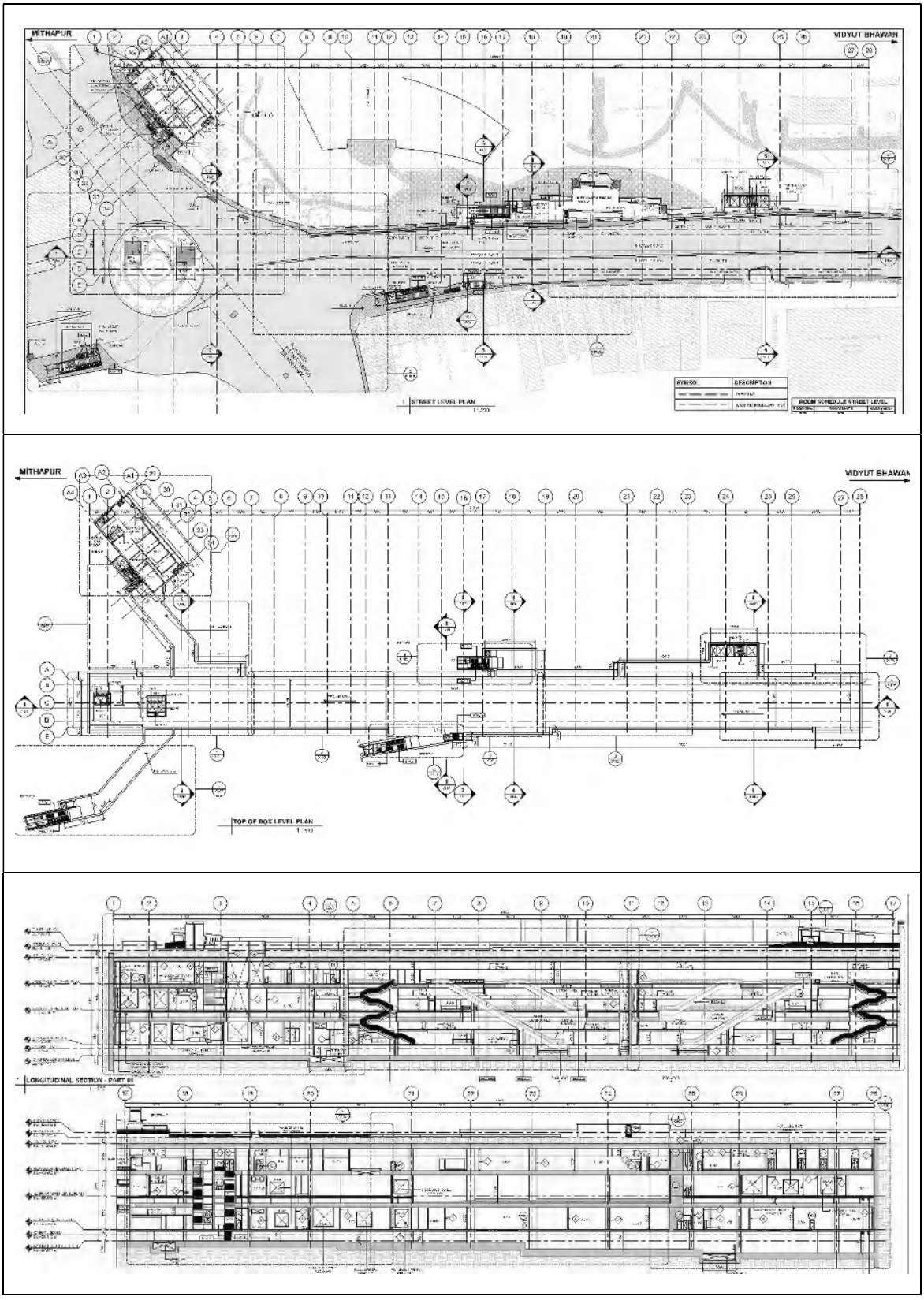

Source: PMRCL/DMRC

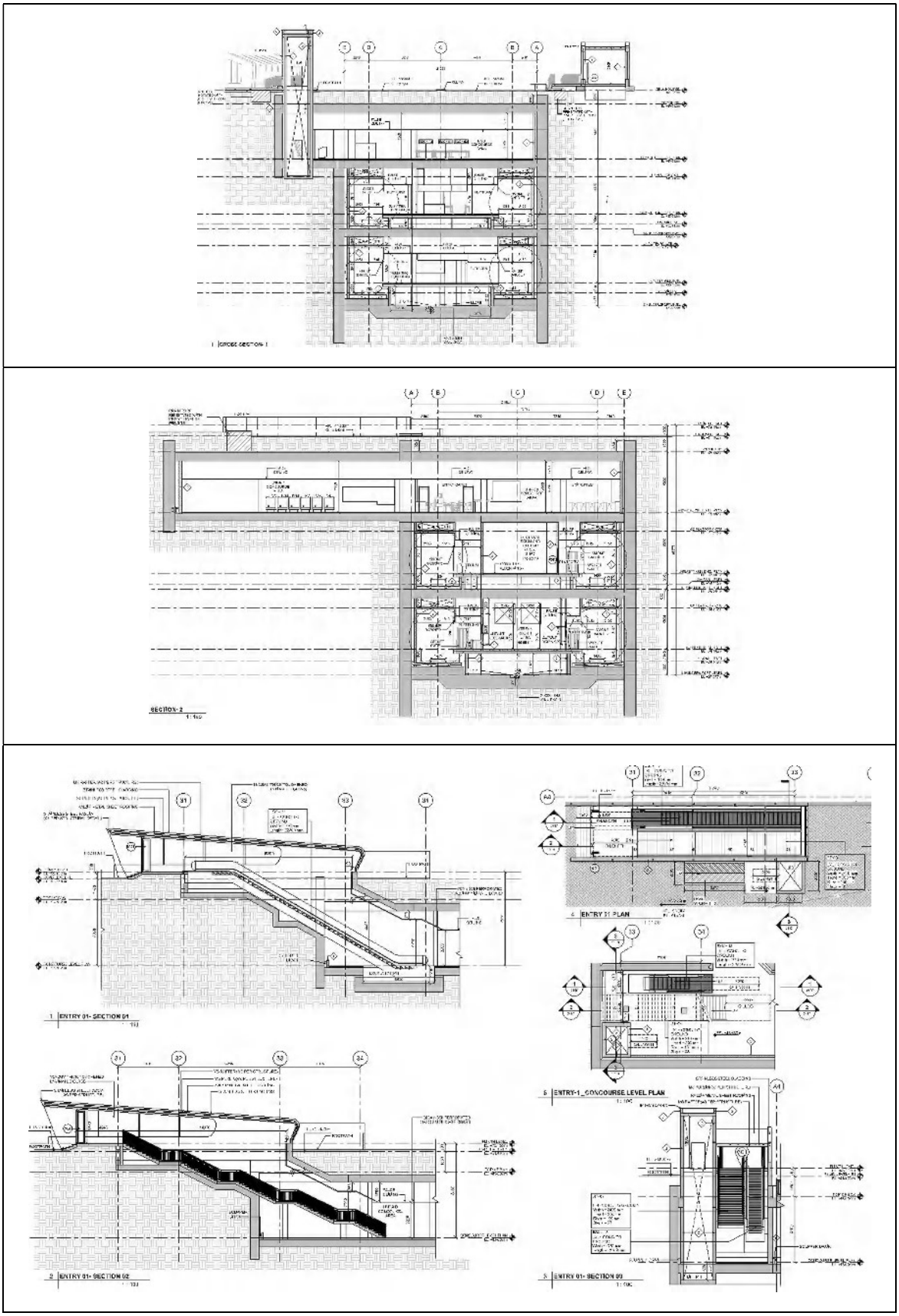
**Figure 5-66: Corridor1 ST08 Vikas Bhawan**




Source: PMRCL/DMRC

**Figure 5-67: Corridor1 ST09 Vidyut Bhawan**


MITHAPUR
VIDYUT BHAWAN
STREET LEVEL PLAN
TOP OF BOX LEVEL PLAN
LONGITUDINAL SECTION - PART 01



Source: PMRCL/DMRC

**Figure 5-68: Corridor1 ST10 Patna Junction**

### 5.4.2 Reviews of Existing Studies and Proposals for Improvement

India has experienced a number of metro construction projects. The DPR describes the civil works' overall plan based on their experiences. The following sections summarize major review points in each investigation, planning, basic design, and construction stage.

In addition, JST's proposals and recommendations for improvement of civil plan in further stages are described.

#### (1) Design

##### 1) Elevated section

The packages of viaduct section of the Corridor 1 and the Corridor 2 have been contracted. Viaduct section between Corridor 2 ST09 Khemichak and Corridor 2 ST11 Zero Mile via Corridor 2 ST10 Bootnath are constructing now. Type of elevated structure and design specification are referred to Delhi Metro Project. It is adequate selection of civil structure.



Corridor 2 ST09 Khemnichak




Corridor 2 ST11 Zero Mile

Source: JST

**Figure 5-69: Construction Condition of Elevated Section of Corridor2 (2022/5/15)**

##### 2) Underground section

**Underground Station**

The DPR described the use of diaphragm wall and secant piles and sheet pile which are often used in India for underground structure construction. These retaining walls have water stopping function, then adopting these retaining wall to the Patna Metro Rail Construction Project is adequate due to soil and water level condition which was surveyed by geotechnical investigation.

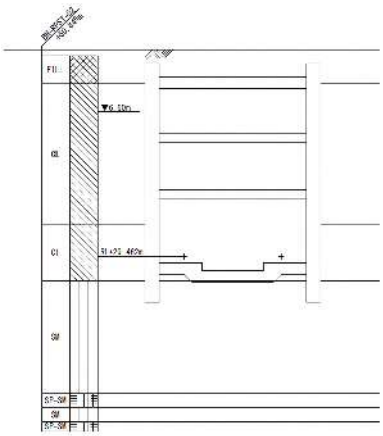
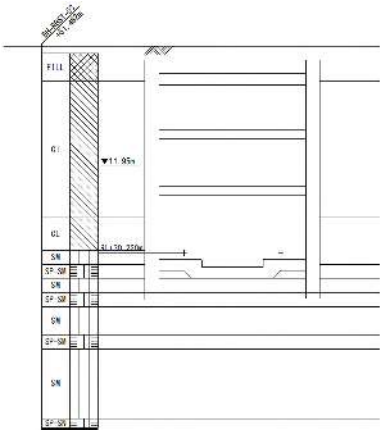
In addition, since detailed design of the underground station is carried out by the Contractor, it is not possible to confirm the reinforcement rebar arrangement in JICA survey, so it was not to confirm whether the reinforcement rebar arrangement can ensure the quality of concrete.

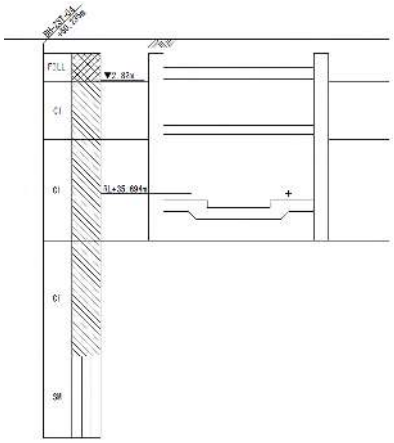
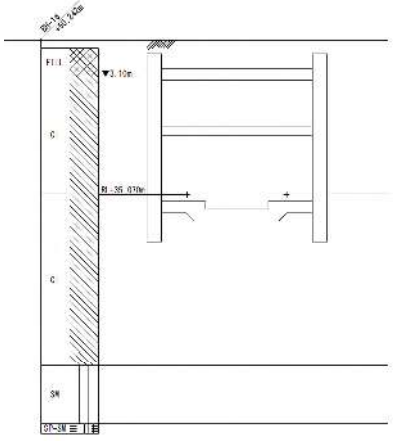
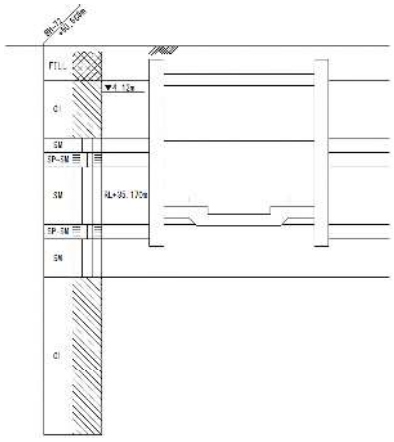
The review results of civil engineering part are shown below.

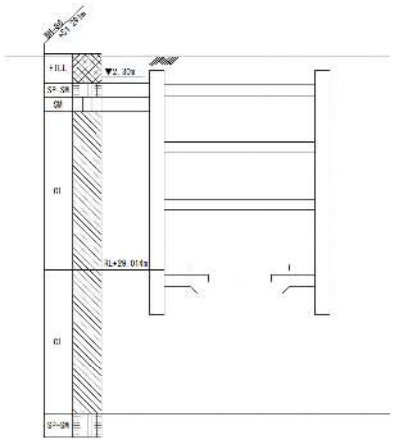
- **Corridor 1:** The received basic design drawing of the underground station from PMRCL/DMRC applies the case of structure of Delhi Metro Project and the civil design specification is the same as the latest Delhi Metro Project. At this time, it is no objection for basic design drawing of civil.
- **Corridor 2:** The received basic design drawing of the underground station from PMRCL/DMRC applies the case of structure of Delhi Metro Project, and the civil design specification is the same as the latest Delhi Metro Project. At this time, it is no objection for basic design drawing of civil.

Next the below table shows the soil condition of each underground station in Corridor1.

**Table 5-27: Soil Condition of each Underground Station in Coridor1**

| Station | Figure | Soil Condition | |
|---|---|---|---|
| | | Station BOX | Penetration of D--Wall |
| Rukanpura Station |  Bor. BH-RPST-02 | Cl(GL-3.0m to 18.0m) Brownish, Firm to very Stiff, Clayey Silt of medium plasticity | SM(GL-24.0m to 36.0m) Brownish, Dense to Very Dense, Silty Sand |
| | | Cl(GL-18.0m to 24.0m) Brownish, Hard, Clayey Silt of medium plasticity | |
| Raja Bazar Station |  Bor. BH-RBST-03 | Cl(GL-3.0m to 17.5m) Brownish, Medium Stiff to very stiff, Clayey Silt of medium plasticity | SM(GL-24.0m to 25.5m) Brownish, Very dense Silty sand |
| | | Cl(GL-17.5m to 21.0m) Brownish, Hard, Clayey Silt of medium plasticity | SP-SM(GL-25.5m to 27.0m) Brownish, Very dense Silty sand |
| | | SM(GL-21.0m to 22.5m) Brownish, Very dense Silty sand | SM(GL-27.0m to 30.0m) Brownish, Very dense Silty sand |
| | | SP-SM(GL-22.5m to 24.m) Brownish, Very dense Silty sand | SP-SM(GL-30.0m to 31.5m) Brownish, Very dense Silty sand |

| Station | Figure | Soil Condition | |
|---|---|---|---|
| | | **Station BOX** | **Penetration of D--Wall** |
| Patna Zoo Station |  Bor. BH-ZST-04 | Cl(GL-3.0m to 9.0m)<br>Greyish,<br>Medium stiff to stiff, Clayey silt of medium plasticity | Cl(GL-9.0m to 19.5m)<br>Brownish, Stiff to very stiff, Clayey Silt of medium plasticity |
| | | Cl(GL-9.0m to 19.5m)<br>Brownish, Stiff to very stiff, Clayey Silt of medium plasticity | Cl(GL-19.5m to 31.5m)<br>Brownish, Hard, Clayey Silt of medium plasticity |
| | | | SM(GL-31.5m to 40.0m)<br>Brownish,<br>Very dense Silty sand |
| Vikas Bhawan Station |  Bor. BH-61 | Cl(GL-3.0m to 15.0m)<br>Brownish,<br>Firm to Stiff, Clayey Silt of medium plasticity | CL(GL-15.0m to 33.0m)<br>Brownish,<br>Very Stiff to Hard, Clayey Silt of medium plasticity |
| | | CL(GL-15.0m to 33.0m)<br>Brownish,<br>Very Stiff to Hard, Clayey Silt of medium plasticity | SM(GL-33.0m to 39.0m)<br>Brownish,<br>Very dense Silty sand |
| Vidyut Bhawan Station |  Bor.BH-72 | Cl(GL-3.0m to 9.0m)<br>Greyish, Medium stiff to stiff, Clayey silt of medium plasticity | SP-SM(GL-18.0m to 19.5m)<br>Brownish, medium dense to dense. Silty sand |
| | | SM(GL-9.0m to 10.5m)<br>Brownish, medium dense to dense. Silty sand | SM (GL-19.5m to 23.5m)<br>Brownish, medium dense to dense. Silty sand |
| | | SP-SM(GL-10.5m to 12.0m)<br>Brownish, medium dense to dense. Silty sand | Cl(GL-23.5m to 40.0m)<br>Brownish,<br>Hard, Clayey silt of medium plasticity |
| | | SM(GL-12.0m to 18.0m)<br>Brownish, medium dense to dense. Silty sand | |

| Station | Figure | Soil Condition | |
|---|---|---|---|
| | | **Station BOX** | **Penetration of D--Wall** |
| Patna Junction Station |  Bor. BH-86 | SP-SM(GL-3.0m to 4.5m) Brownish, Loose, Silty Sand | Cl(GL-22.5m to 37.5m) Brownish, Hard, Clayey Silt of medium plasticity |
| | | SM(GL-4.5m to 6.0m) Brownish, Loose, Silty Sand | |
| | | Cl(GL-6.0m to 22.5m) Brownish, Stiff to Very Stiff, Clayey Silt of medium plasticity | SP-SM(GL-37.5m to 40.0m) Brownish, Very Dense, Silty Sand |
| | | Cl(GL-22.5m to 37.5m) Brownish, Hard, Clayey Silt of medium plasticity | |

Source: JST

As shown in the above table, soil conditions at the embed of the D-wall are classified below

Case1: Clayey Silt (Zoo Station, Vikas Bhawan Station, and Patna Junction Station)
Case2: Silty Sand (Rukanpura Station and Raja Bazar Station)
Case3: Alternation Strata of Silty sand and Clayey Silt (Vidyut Bhawan Station)

Embed length of D-Wall to be determined by stability analysis of the bottom of excavation (e.g. heaving, boiling, bottom heaving, and piping) and balance penetration depth analysis.

It means that the embed length of the D-wall at each station is different.

Also, if de-watering method will be applied during excavation of underground station, degree of ground settlement shall be examined by the Contractor.

JST confirmed the below examination to PMRCL/DMRC.

1) Have you determined the embed length of the station's D-wall in the basic design stage?
2) If yes, how to consider the cost estimation of civil works of the station?
3) If no, please determine the embed length of the station's D-wall in the basic design stage, because the cost of the embed length of the station's D-wall reflects the cost of Civil work.

The below comment is replied from PMRCL/DMRC.

1) No
2) Not applicable
3) Embedded length of D wall will be proposed by the construction contractor being Design and Built contract. It is already included in the lump sum scope of work of the Construction Contractor. Cost of Underground work has been estimated on the basis of built-up floor area.

**TBM Alignment**

- JST was confirmed degree of proximity between the existing Patriputra Bridge pile foundation and TBM, and vertical alignment of TBM under the each river point.
- **Corridor 1:** The proximate (4) four TBM are planned on the north side of Corridor1 ST10 Patna Junction which is the first case in India. In Japan, there are proximate (4) four TBM construction such as Chofu Station on the Keio Main Line and Misasagi Station on the Kyoto Tozai Line.
- The two TBMs between Corridor 2 ST01Patna Junction and Corridor2 ST02 Akashuvani have already been contracted in the Corridor 2 package PC03. This construction sequence was confirmed and reported in this DFR section "5.4.2 Reviews of Existing Studies and Proposals for Improvement (2) Construction 8) Special construction methodology (ii) Integrated underground station and (iii) TBM tunnelling with minor clearance"

The below table shows a comparison table of 4 TBMs cases between Corridor1 ST10 Patna Junction Station and case of in Japan.

**Table 5-28: Comparison Table of 4 TBMs Cases between Patna Junction Station and Case of in Japan**

| | Patna Junction Station | Keio Chofu Sta. (JPN) | Kyoto Subway (JPN) |
|---|---|---|---|
| TBM Segment external diameter | 6.35m<br>(TBM excavation diameter:6.70m) | 6.70m | 5.84 m |
| TBM vertical clearance between both segments | 3.57m(0.56D) | Less than 1m | 0.86 m |
| TBM procedure | Latest construction sequence;<br>Upper TBM (Corrior2) is first<br>Recommendation;<br>Lower TBM (Corrior1) is first | Lower TBM was first | Lower TBM was first |
| Ground condition | Brownish Very Stiff to Hard Clayey stiff of medium plasticity | Sand and gravel | Shale |
| Ground water | GL (-1m) ~ (-4 m) | Submerged | GL -2 m |
| Soil improvement | — | Soil improvement for water stop | — |

Source: JST

The below table shows a comparison table of vertical 2 TBMs cases in Japan.

**Table 5-29: Comparison Table of Vertical 2 TBMs Case in Japan**

| | Shin Okachimati (JPN) | Ooimachi Station (JPN) |
|---|---|---|
| TBM Segment external diameter | Upper TBM: Ooedo Line 5.3m (single track)<br>Lower TBM: Tsukuba Express Line 10.0m (double track) | Upper and Lower TBM: 10.1m (single track with platform) |
| TBM vertical clearance between both segments | 7.3m (0.73D) | 1.0m |
| TBM procedure | Upper TBM was first | Lower TBM was first |
| Ground condition | Sand and gravel | Upper TBM: Clay<br>Lower TBM: Sand and gravel |
| Ground water | Submerged | Submerged |
| Soil improvement | Soil improvement for water stop | - |

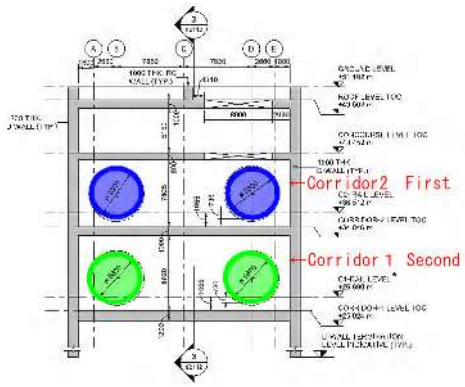
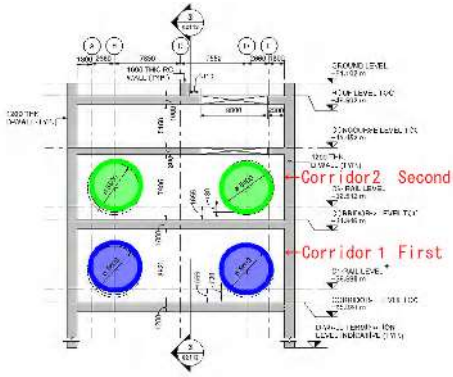
Source: JST

As mentioned above the TBM procedure of the Contractor package of PC03 considers upper TBM first.

However, JST recommends lower TBM (Cooridor1) first for taking into consideration of safety construction.

The below table shows the comparison table for risk assessment of alternative TBM construction sequence.

**Table 5-30: Comparison Table for TBM sequence at Patna Junction Station**

| | **Case A**<br>**Latest TBM construction sequence** | **Case B**<br>**Alternative** |
|---|---|---|
| TBM construction sequence | Upper TBM (Corrior2) is first | Upper TBM (Corrior1) is first |
| |  |  |
| Influence of Upper/Lower TBM | • When lower TBM drives, upper TBM will receive settlement by lower TBM driving directly.<br>• Then segment lining of upper TBM will be deformed and beard additional stress. | • When upper TBM drives, lower TBM will receive rebound deformation by upper TBM driving directly.<br>• Then segment lining of lower TBM will be deformed and beard additional stress. |
| | Rebound value of lower TBM of Case B is less than settlement value of upper TBM of Case A | |
| Countermeasure | • Strengthen upper TBM segment lining.(e.g composite segment, steel segment) | • Strengthen lower TBM segment lining.(e.g composite segment, steel segment)<br>• Arrangement of propping into lower TBM segment |
| Interface | Please refer "5.4.2 Reviews of Existing Studies and Proposals for Improvement (2) Construction 8) Special construction methodology (iii) TBM tunnelling with minor clearance" | |

Source: JST

JST recommended Case B to PMRCL/DMRC, the below comment is replied from PMRCL/DMRC

> Construction sequence of Patna Junction Metro Station is as follows, as per contract condition of PC-03:
>
> Firstly, the Corridor-2 PC-03 Contractor will construct the upper twin box tunnel by method other than TBM near Patna Station.
>
> Later, Corridor-1 PC-05 Contractor will construct the lower tunnels by the construction methodology specified by Corridor-2 Contractor so that there are no damages to the tunnel constructed by Corridor-2 PC-03 Contractor.

And, JST requested that the PC-05 Contractor should verify the construction methodology and analysis by the PC-03 Contractor and monitor their tunnels while proceeding with its TBMs.

This collaborative approach will work practically, and it is necessary that the bidding documents of PC-

05 should enclose the exact requirement.

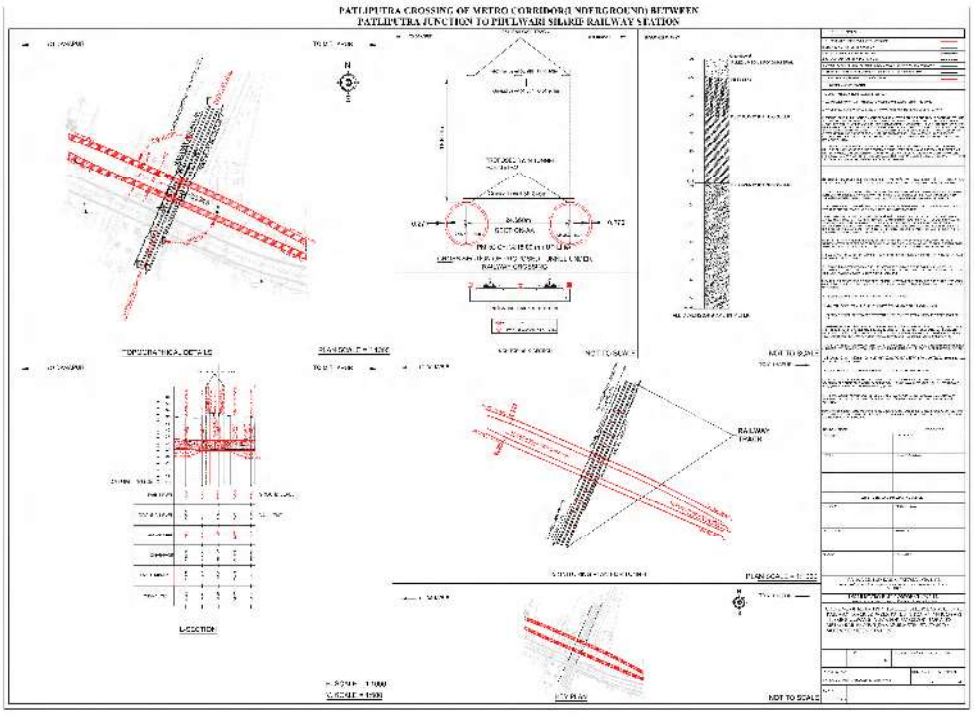
The below comment is replied from PMRCL/DMRC.

| |
|---|
| Clauses for construction methodology of Interface at Patna Station has been added in Bidding Documents of PC-05 and PC-03. |

**TBM crossing point with Indian National Railway**

TBM will pass under the existing Indian railway. The below figures show the monitoring plan prepared by PMRCL/DMRC.

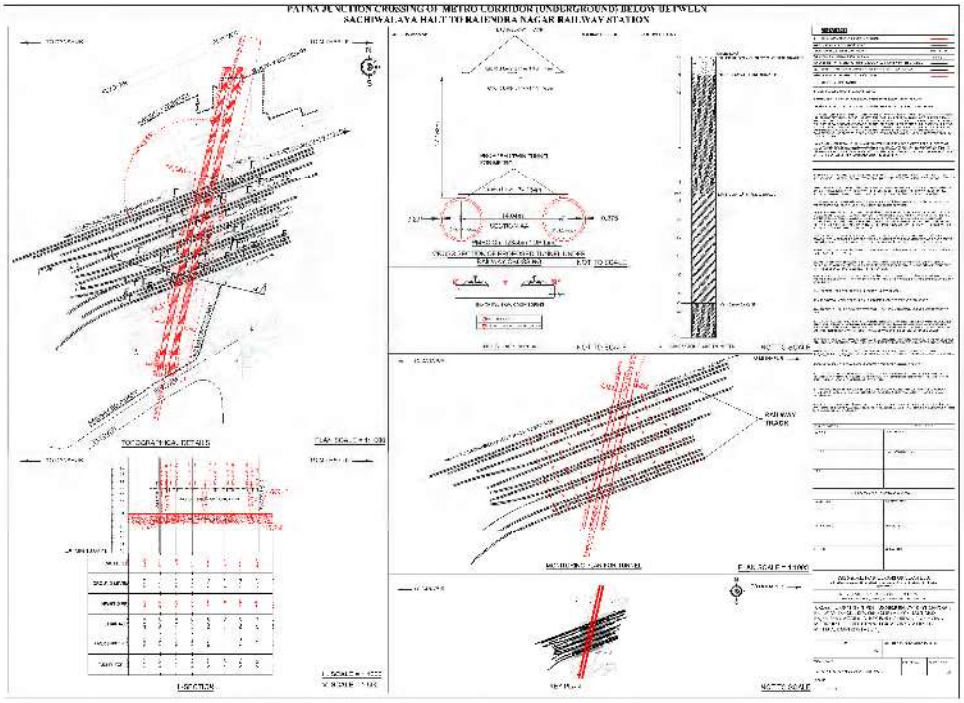
a) Partriputura Crossing of Metro Corridor 1 (Underground) Between Patriputra Junction to Phulwari Sharif Railway Station




Source: PMRCL/DMRC

**Figure 5-70: Monitoring Plan at Partriputura Crossing**

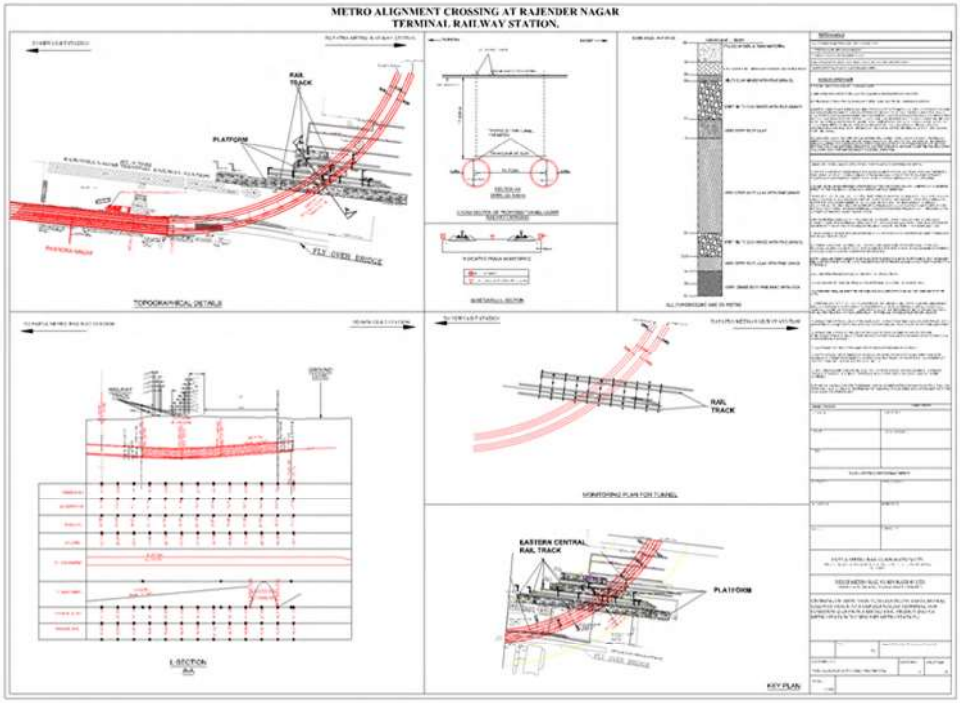
b) Patna Junction crossing of Metro Corridor1 (underground) below between Sachiwalay Halt to Rajendra Nagar Railway Station




Source: PMRCL/DMRC

**Figure 5-71: Monitoring Plan at Patna Junction Crossing**

c) Metro alignment crossing at Rajendra Nagar Terminal Railway Station in Corridor 2



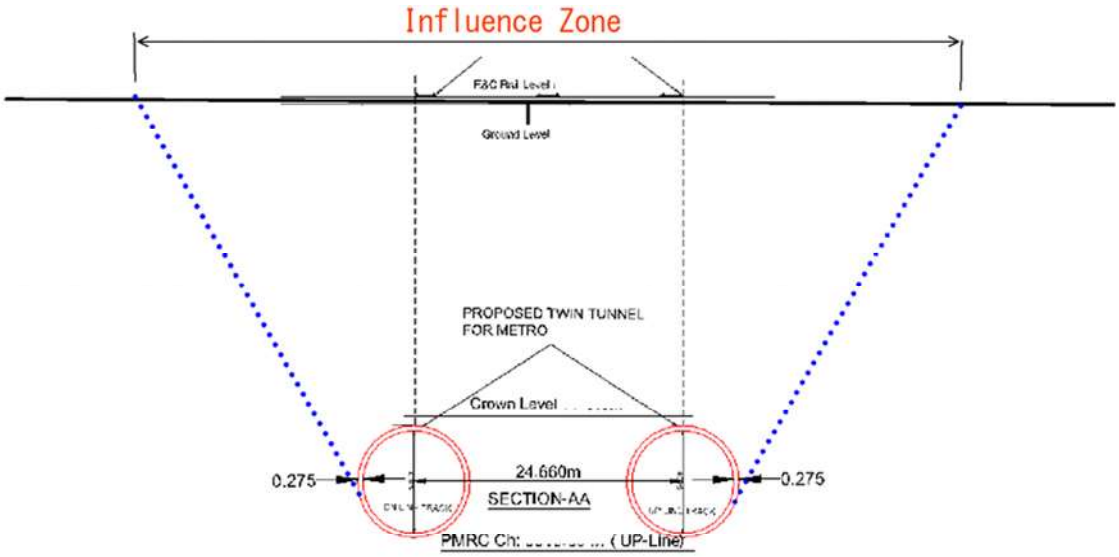

Source: PMRCL/DMRC

**Figure 5-72: Monitoring Plan at Rajendra Nagar Crossing**

The crossing angle between TBM and the existing national railway is;

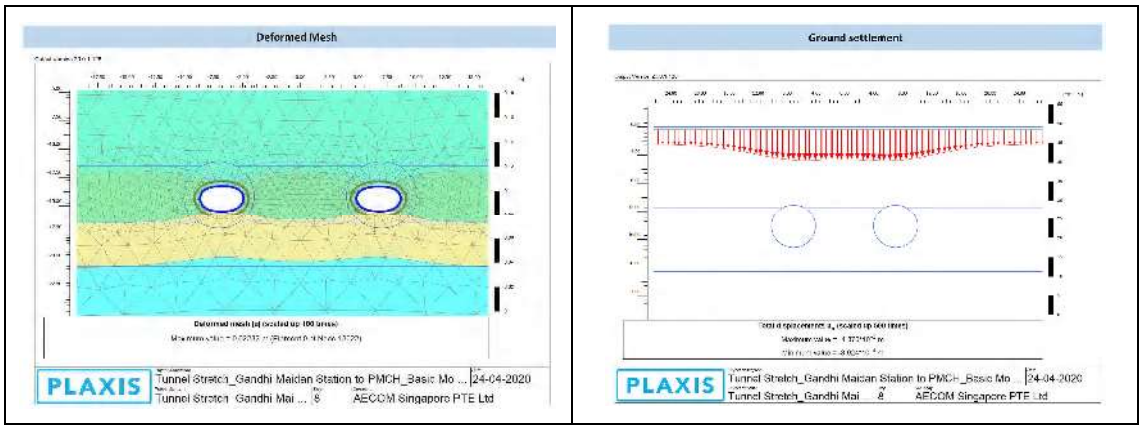
1) Partriputura: Right-angled plane crossing
2) Patna Junction; At an oblique angle crossing
3) Rajendra Nagar: Ditto

JST proposes modified monitoring area above 2) and 3) crossing point under take into consideration influence zone by TBM driving, modified monitoring zone has to be set from TBM alignment in parallel. And the monitoring zone shall be determined by the result of the Contractor's Finite Element Method (FEM) analysis.




Source: PMRCL/DMRC

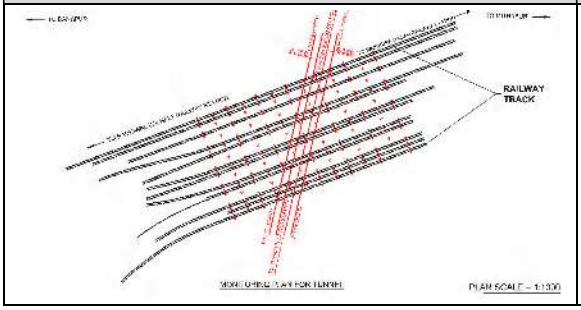
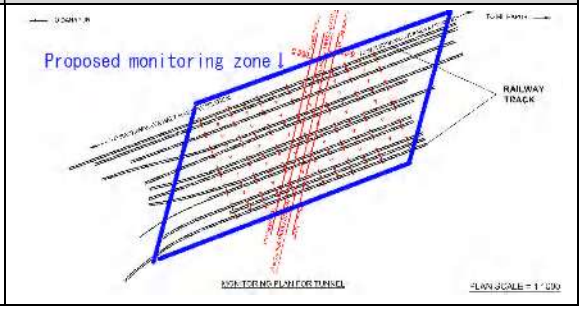
**Figure 5-73: Influence Zone by TBM Driving**




Source: PMRCL/DMRC

**Figure 5-74: Example of FEM Analysis**

2) Patna Junction

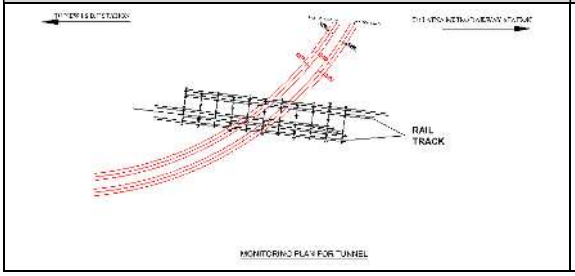
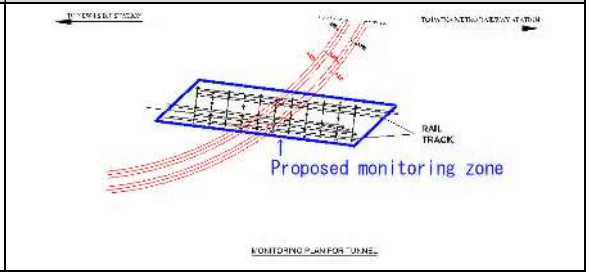
| Original monitoring zone | Proposed monitoring zone |
|---|---|
|  |  |



Source: JST adds proposed monitoring zone

**Figure 5-75: Proposed Monitoring Zone at Patna Junction**

3) Rajendra Nagar

| Original monitoring zone | Proposed monitoring zone |
|---|---|
|  |  |



Source: JST adds proposed monitoring zone

**Figure 5-76: Proposed Monitoring Zone at Rajendra Nagar Crossing**

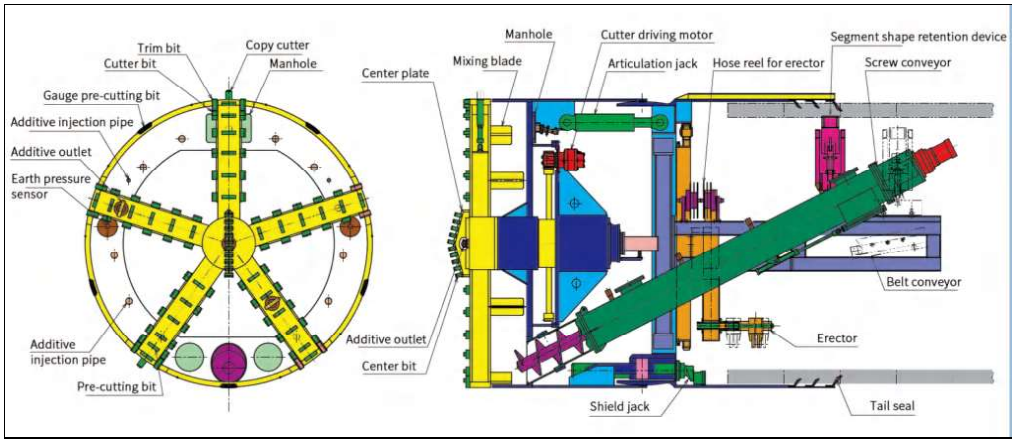
The below comment is replied from PMRCL/DMRC

| |
|---|
| The Recommendation for monitoring zone at the TBM crossing point with Indian National Railway has been noted and shall be taken due care of at the time of construction by the Contractor. |

**TBM Machine**

DPR described Earth pressure type (EPB), Mud-pressure type and Slurry type, TBM machine will be selected by the Contractor. Earth pressure type is one of the suitable TBM machine in Patna Metro for sections passing through the silt layer.

When TBM passes through the sandy soil with low uniformity coefficient, it is necessary to take care the selection of TBM machine.




Source: UGITEC (https://ugitec.co.jp/en/)

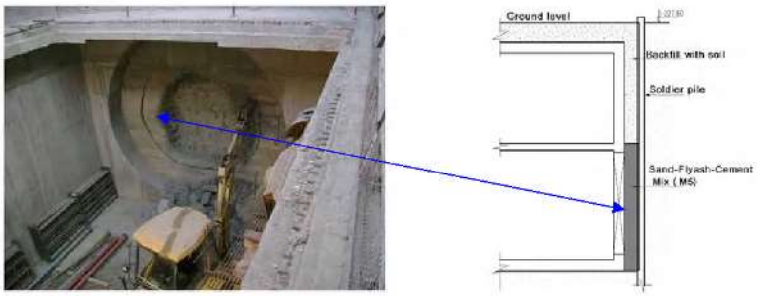
**Figure 5-77: General Assembly Drawing of EPB TBM**

**The construction method of TBM launching and retrieval**

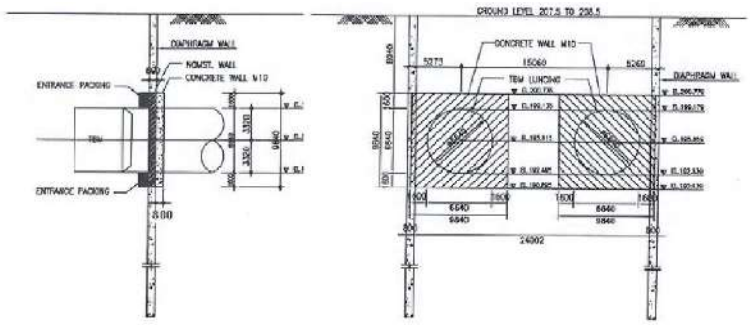
Regarding the construction method of TBM launching and retrieval, the construction method will be selected by the Contractor under Design-Build contract. The tunnel eye protection method of Delhi Metro Phase2 is shown below the figure for reference.




Case1 (Launching: Used Steel Pipe Pile)




Case2 (Launching: Used M5 concrete between temporary retaining wall and end wall of station)




Case3 (Launching: Used M10 concrete outside of diaphragm end wall of station)



Case4 (Retrieval: The diaphragm wall was demolished by breaker up to soil face reinforcement. Soil improvement of the diaphragm wall was not required.)

Source:
J. Tyag (Delhi Metro Railway Corporation, Delhi, INDIA), S. Lowry , K. Yamaoka , C. Izumi (Oriental Consultants Co., Ltd. Tokyo, JAPAN;A Study of Tunnel Eye Breaking Method for the Delhi Metro Phase-IIA Study of Tunnel Eye Breaking Method for the Delhi Metro Phase-II, WTC2010 VANCOUVER

**Figure 5-78: The Construction Method of TBM Launching and Retrieval**

**Points of attention for TBM construction**

The below table shows points of attention for TBM construction which were described in "Standards Specifications for Tunneling - 2016 : Shield Tunnels, JAPAN Society of Civil Engineer"

**Table 5-31: Points of attention for TBM Construction**

| Item | Point of attention |
|---|---|
| 3.4 Driving Management of an Earth Pressure Balanced (EBP) Shield | (1) Face stability should be maintained while the cutting face is excavated by considering the ground conditions and the diameter of the tunnel.<br>(2) The pressure in the cutter chamber, plastic flow and excavated volume should be carefully controlled to maintain face stability, while fluidity and water tightness of excavated soil should be maintained by adding additives suited to the geological conditions.<br>(3) A muck disposal facility should be selected in consideration of the soil characteristics. The capacity of the facility should be planned to meet the excavation schedule. |
| 3.6 Primary Lining | As soon as excavation is completed, the primary ling should be installed correctly and securely in the prescribed way. |
| 3.7 Backfill Grounding | Backfill grouting should be done with the most suitable grout material and by the most suitable grouting method. Backfill grouting should be done simultaneously with shield advancement or immediately after shield restarting so that the tail void is completely filled and any ground loosening or ground settlement is prevented. |
| 3.8 Waterproofing and Corrosion Protection | (1) Waterproofing should be undertaken by a method that fits working conditions in order to meet the purpose of the tunnel.<br>(2) Corrosion protection should be undertaken to secure durability of the primary lining, especially when a secondary is not to be constructed, by taking into account the use and environmental conditions of the tunnel. |
| 3.10 Auxiliary Measure | The ground is likely to become unstable because of water inflow or a lack of strength in sections where the shield starts or arrives at a shaft, where tunnels are connected, where a tunnel cross section is enlarged, when bits are replaced, when obstacles are removed, at sharp curves, when the overburden is shallow, or when construction is in the close proximity of existing structures. In such places, appropriate auxiliary measures should be taken as required in combination with soil improvement measures to ensure ground improvement. |
| 3.11 Ground Movements and Prevention Measures | Ground movements are affected by the planning and design of a tunnel, geological conditions, and construction conditions. Adverse influences on the surroundings should be minimized by applying proper construction methods and executing prudent construction management. |
| 4.1 Tunnel Construction with Shallow Overburden | When a shield tunnel is constructed with shallow overburden, the face pressure control and backfill grouting should be carefully managed so that influence on the ground surface and /or underground utilities should be minimized. Auxiliary measures should be taken as required to avoid tunnel uplift or segment deformation. |

| Item | Point of attention |
|---|---|
| 4.6 Rapid Operation | Rapid operation requires not only enhancing the capabilities of individual pieces of equipment and systems, but also selecting efficient combinations thereof. Quality should be fully ensured during construction and work should be carried out safely. |
| 4.12 Neighboring Construction | When shield tunnel is planned by neighbouring construction, preliminary consideration of the influence and necessary protection measures should be taken.<br>Existing structures should be monitored during construction and the influence on existing structures carefully observed. |
| 4.13 Construction of Multiple Parallel Shield Tunnels | When two or more parallel shield tunnels ate to be constructed, sufficient attention should be paid to the mutual influence of each tunnel. Ground and tunnel movements should be carefully observed. Auxiliary measures or reinforcement of the tunnel should be taken when necessary. |
| 4.14 Seabed or River Crossing | When a tunnel crosses under a seabed or a river, secure construction operation in consideration of the ground and bay or river conditions should be studied carefully. |

Source: Standards Specifications for Tunneling - 2016: Shield Tunnels, JAPAN Society of Civil Engineer

**Cross Passage**

The metro projects in India adopt NFPA130 and cross passage are planned in TBM section between station and station. The number of cross passages for the Corridor 1 and 2 are shown in the table below.

The construction method of the cross passage is the NATM method with dewatering usually in Metro Project in India.

**Table 5-32: The number of Cross Passage for Corridor 1**

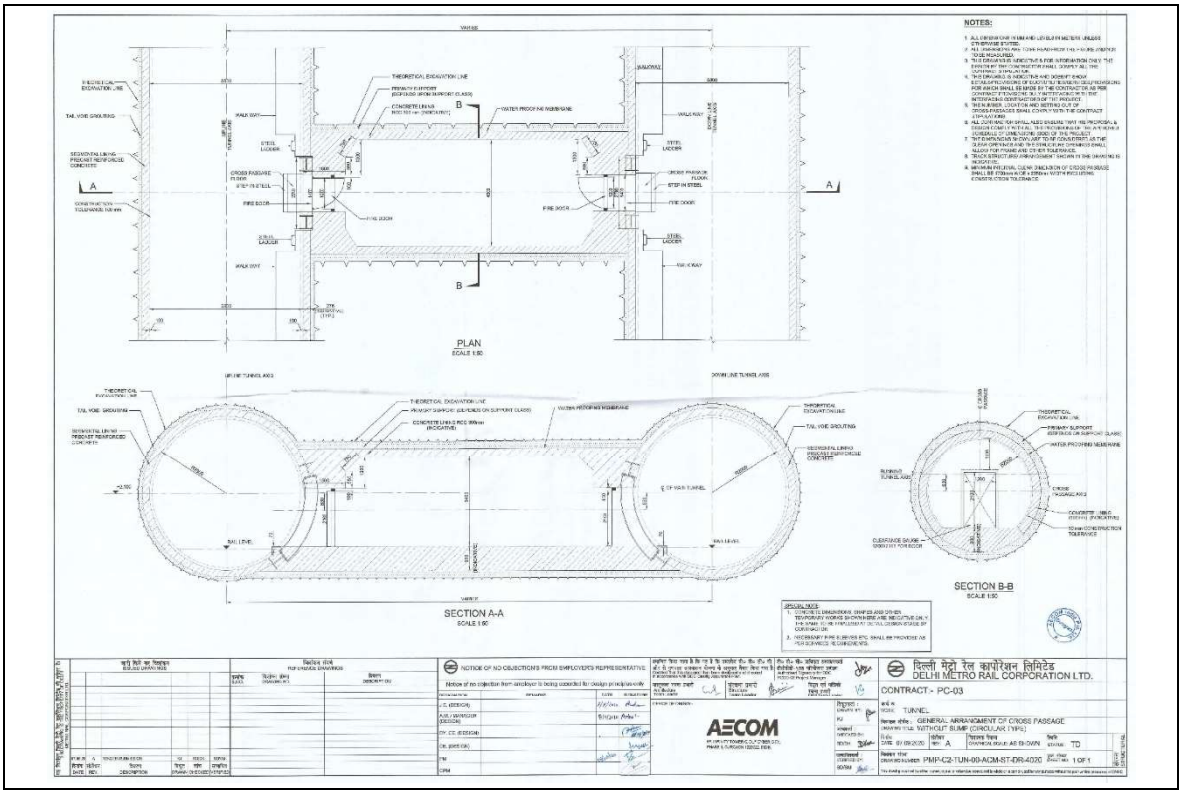
| Location | Cross Passage | Cross Passage with Sump |
|---|---|---|
| From Ramp Shaft to ST 05 Rukanpura | 1 | 1 |
| From ST05 Rukanpura to ST06 Raja Bazar | | 1 |
| From ST06 Raja Bazar to ST07 Patna Zoo | 5 | 1 |
| From ST07 Patna Zoo to ST08 Vikas Bahawan | 2 | |
| From ST08 Vikas Bahawan to ST09 Vidyut Bahawan | 1 | 1 |
| From ST09 Vidyut Bahawan to ST10 Patna Junction | 1 | 1 |
| From ST10 Patna Junction to Ramp Shaft | 1 | 1 |
| **Total** | **11** | **6** |

Source: JST

**Table 5-33: The Number of Cross Passage for Corridor 2**

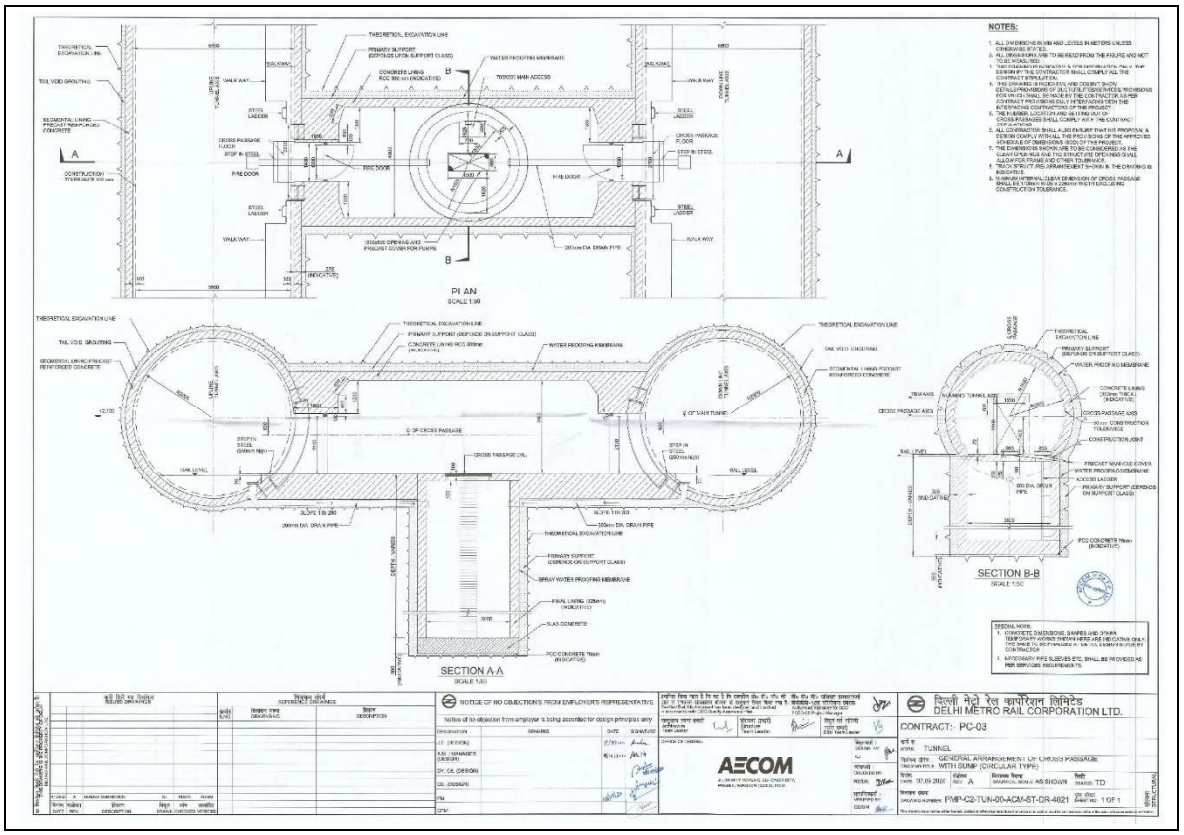
| Location | Cross Passage | Cross Passage with Sump |
|---|---|---|
| From ST01 Patna Junction on to ST02 Akashuvani | 1 | |
| From ST02 Akashuvani to ST03 Gandhi Maidan | | 1 |
| From ST03 Gandhi Maidan to ST04 PMCH | | 1 |
| From ST04 PMCH to ST05 Univercity | 1 | 1 |
| From ST05 Univercity to ST06 Moin UL Haq | 2 | 1 |
| From ST06 Moin Ul Haq to ST07 Rajendra Nagar | | 1 |
| From ST07 Rajendra Nagar to Ramp Shaft | 1 | |
| **Total** | **5** | **5** |

Source: JST




Source: PMRCL/DMRC

**Figure 5-79: General Arrangement of Cross Passage without Sump**




Source: PMRCL/DMRC

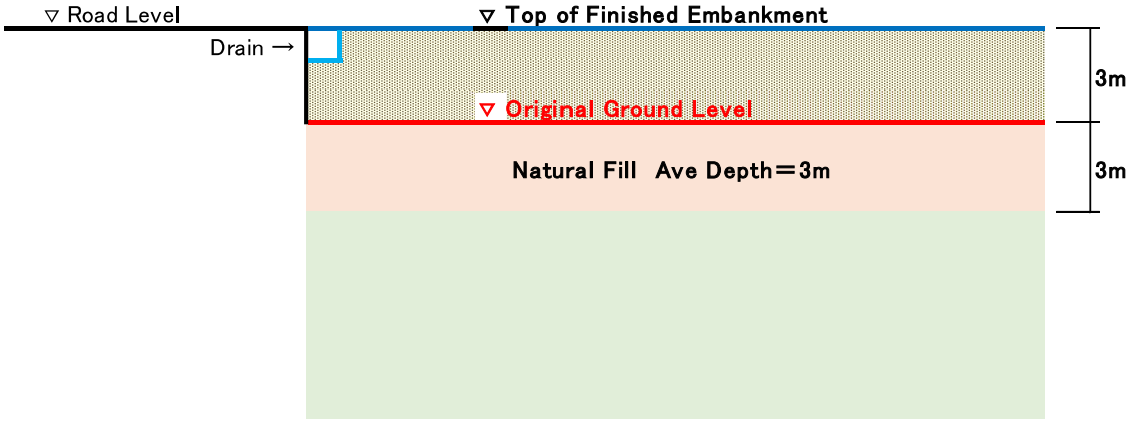
**Figure 5-80: General Arrangement of Cross Passage with Sump**

### 3) Depot Civil

JST has received Tender Document PC04 for Depot.

JST has submitted some queries to PMRCL/DMRC as follows:

1. Observations
   (1) Geotechnical Investigation Report
      1) The depot area is mildly undulating topography with relatively high water table depths ranging between 2.90 m to 4.05 m below existing grades.
      2) Uniform fill depths of unknown compaction and composition have been observed from the borelog and Geotechnical Lab data.
      3) No lab testing on the conditions of existing fill soil have been observed
   (2) Tender Document
      1) Foundation recommendations have been reviewed for the Depot Area for both Open and Pile foundations. In areas of Boreholes BH-01 and BH-02,
      2) The tender document for PC02 for Earthwork, Section S.02, provides adequate provisions for excavation and FILL
      3) Borrow material for structural fill with c=0 and phi=$30^0$, density = 2.1 tonnes/$m^3$ has been considered, which appear to be adequate.
2. Comments
   (1) Embankment
      1) Top of embankment level has been considered at existing road grades. Accordingly, it is understood that the existing FILL MATERIAL will be removed completely, and hence, will not have any bearing on the open foundation.
      2) Structural fill material has been proposed from 3.0 m above existing ground level but the finished level/ top of embankment or structural fill is to be clarified.
      3) Final soil compaction of 95% MDD (Maximum Dry Density) has been proposed which is adequate, provided compaction up to this level is done in lifts. This may be clarified.




   (2) Settlement Analysis
      1) Settlement analysis of the natural ground within the zone/bulb of influence, arising out of the compaction process of the embankment, needs to be considered, as also OCR calculations from UDS.
      2) It is observed that the total thickness of structural fill has been proposed at (3m: the existing FILL MATERIAL) plus (3.0m: Embankment Material) i.e., 6m.

3) Any settlement arising out of the compaction of 6.0 m structural fill on existing FILL MATERIAL grade and rail bed road, ballast, sleeper, rail and train load with impact or spread foundation load of building needs to be taken into consideration.
4) It is noted that settlement analysis have been considered only for borehole BH-03, without any clear indication of the zone of influence of settlement of natural ground at the time of compaction of high embankment. The depth of the zone of influence, and its corresponding settlement analysis at various depths in natural soil, below formation level, may be clarified.

(3) Height of Structural Fill and Depot Protection from Force Majeure events

1) It is understood that the structural fill height is planned up to existing road level.
2) To avoid any future damage to the Depot area arising out of
   i) flooding/greater than designed rainfall,
   ii) progressive enhancement of adjoining city in the future
   - there would be a possibility of drainage inflow from the road to inside the depot area, which will need to be addressed at this stage.
   - Accordingly, the structural fill height above the existing city road level may be reviewed to avoid any possible flooding inside the depot area, which could cause significant damage. It may be pointed out that a Nala (drain) and an adjoining pond, in close vicinity of the Depot area, has the potential to overflow into the depot area, in the event of more than designed rainfall design for the Depot.

(4) Open and Pile Foundation

1) Normal bored cast in-situ piles have been recommended, wherein the cutoff depth of pile has been indicated at 3 m below existing grades.
2) Depth of piles have been tentatively proposed from 28m to 32 m below existing grades.
3) Pile diameter ranges have been assumed between 1,000 mm and 1,500 mm, for the structure foundations.
4) It is understood that the pile foundation recommendations, summarized above, and, in section 2.8 of the Geotechnical Report, is based on the typical loadings assumed for the structures in the depot area. This may be clarified.
5) Pile Foundations have been considered at the location of boreholes BH-01 and BH-02, whereas open foundations (isolated, square footings) have been proposed at the location of Borehole-03.
6) It is observed in the Depot Layout Plan, BH-01 is in the general vicinity of the residential areas, entry line, exit line, Auto coach washing plant, Control Room for Washing Plant, and underground tanks.
7) Similarly, BH-02 does not appear to be in the general vicinity of any structure location vis a vis the Depot layout Plan.
8) BH-03 is located in the general vicinity of most of the structures such as covered stabling yard, auxiliary substation (ASS), ETU office building and Compressor Room for Pneumatic Supply, amongst others.
9) Based on the above, there appears to be a discrepancy/lack of clarity regarding the basis for consideration of the proposal for the foundation type vis a vis foundation location. The same may be clarified in Detailed Design stage with additional geotechnical Survey.

(5) Slope Stability Analysis of Embankment

Slope stabilization analysis/measures for the embankment should be considered to avoid any potential damage to the foundation pad arising due to slope failure of local/global nature due to any reason – natural/manmade.

(6) Borrow material for Embankment

1) The borrow material for Structural fill has been proposed with material of specification c=0 and phi=30 degrees, suitably compacted to 95% MDD, is an acceptable fill material.

2) If any other borrow material is to be considered as an alternative, for the high embankment, such as excavated material from tunnelling operations, which is all Clayey silt (CL-ML or CI material), suitability of this material has to be ascertained prior to using as structural fill material. The borrow material thus used, should be compactable to 95% MDD and should not cause differential settlement/adverse subsurface conditions that may damage to structure foundations.

(7) Flooding Condition

1) Highest Flood Level (HFL) conditions must be taken into account for Embankment design using a suitable recurrence flood interval or any other appropriate level, by the Contractor. As the depot would be housing the stabling lines, and all maintenance and operations facilities, it is suggested that the Embankment design should be considered on a conservative side, to avoid flooding conditions within the depot from adjoining areas at any cost.

- Perimeter Drain, of suitable design, to handle the worst case runoff volume and running continuously along the Depot perimeter, is required.
- The perimeter drain needs to be connected to the existing city drainage system (open/closed) with adequate assurances of continuous drainage at all times and under all conditions.
- Hydrological analysis by the Contractor is necessary avoiding flooding problems arising due to the regional flow of surface runoff during adverse monsoon conditions that can cause the existing drainage facilities to be overwhelmed & ineffective.

2) The actual design and support/stabilization measures of the embankment will be responsibility of the Contractor.

The following table shows reply comment from PMRCL/DMRC.

**Table 5-34: The reply comment of Depot Civil from PMRCL/DMRC**

| Item | Review Comment of JST | Reply Comment of PMRCL/DMRC |
|---|---|---|
| (1) Embankment | 1) Top of embankment level has been considered at existing road grades. Accordingly, it is understood that the existing FILL MATERIAL will be removed completely, and hence, will not have any bearing on the open foundation. | —Additional investigation to determine the Fill material properties will be undertaken in construction stage. Based on the Fill properties, any replacement or improvement of Fill material will be done (if required) for the stability of the embankment and other depot structures. |
| | 2) Structural fill material has been proposed from 3.0 m above existing ground level but the finished level/ top of embankment or structural fill is to be clarified. | —The formation level is 50.3 m. |
| | 3) Final soil compaction of 95% MDD (Maximum Dry Density) has been proposed which is adequate, provided compaction up to this level is done in lifts. This may be clarified. | —Noted. Further to it, necessary tests for embankment has also to be conducted as per RDSO (Research Designs & Standards Organisation) guideline for Railway formation. |
| (2) Settlement Analysis | 1) Settlement analysis of the natural ground within the zone/bulb of influence, arising out of the compaction process of the embankment, needs to be considered, as also OCR calculations from UDS. | —Settlement analysis due to embankment loading will be done by contractor's DDC (Detail Design Consultants) as per relevant IS code and RDSO guideline for Railway formation. |

| Item | Review Comment of JST | Reply Comment of PMRCL/DMRC |
|---|---|---|
| | 3) Any settlement arising out of the compaction of 6.0 m structural fill on existing FILL MATERIAL grade and rail bed road, ballast, sleeper, rail and train load with impact or spread foundation load of building needs to be taken into consideration. | —Settlement analysis due to embankment loading and its impact on Depot structures will be done by contractor's DDC as per relevant IS code and RDSO guideline for Railway formation. |
| | 4) It is noted that settlement analysis have been considered only for borehole BH-03, without any clear indication of the zone of influence of settlement of natural ground at the time of compaction of high embankment. The depth of the zone of influence, and its corresponding settlement analysis at various depths in natural soil, below formation level, may be clarified. | —A typical settlement analysis for an isolated footing of 2.5 m x 2.5 m at depth 1.5 m from the formation level has been shown. Settlement analysis due to embankment loading will be done by contractor's DDC as per relevant IS code and RDSO guideline for Railway formation. |
| (3) Height of Structural Fill and Depot Protection from Catastrophic /Force Majeure events | 2) To avoid any future damage to the Depot area arising out of<br>i) flooding/greater than designed rainfall,<br>ii) progressive enhancement of adjoining city in the future<br>• there would be a possibility of drainage inflow from the road to inside the depot area, which will need to be addressed at this stage.<br>• Accordingly, the structural fill height above the existing city road level may be reviewed to avoid any possible flooding inside the depot area, which could cause significant damage. It may be pointed out that a Nala (drain) and an adjoining pond, in close vicinity of the Depot area, has the potential to overflow into the depot area, in the event of more than designed rainfall design for the Depot. | —Drainage system of Depot is adequate to take care of any water inflow and the connecting road to the depot also have proper drainage system. Any further increase of formation level is not required as all concerns related to flooding and inflow has already been taken care of. |
| (4) Open and Pile Foundation | 4) It is understood that the pile foundation recommendations, summarized above, and, in section 2.8 of the Geotechnical Report, is based on the typical loadings assumed for the structures in the depot area. This may be clarified. | —Specific calculation based on loads from structure will be done by contractor's DDC as per relevant IS code. |
| | 5) Pile Foundations have been considered at the location of boreholes BH-01 and BH-02, whereas open foundations (isolated, square footings) have been proposed at the location of Borehole-03. | —Calculation specific to the type of foundation will be done by contractor's DDC considering relevant borehole data. |
| | 9) Based on the above, there appears to be a discrepancy/lack of clarity regarding the basis for consideration of the proposal for the foundation type vis a vis foundation location. The same may be clarified in Detailed Design stage with additional geotechnical Survey. | —Additional investigation for depot will be untaken in construction stage. The foundation design will be updated by contractor's DDC based on the additional investigation data. |
| (5) Slope Stability Analysis of Embankment | Slope stabilization analysis/measures for the embankment should be considered to avoid any potential damage to the foundation pad arising due to slope failure of local/global nature due to any reason – natural/manmade. | —Embankment design will be done by contractor's DDC as per RDSO guidelines for railway formation. |

| Item | Review Comment of JST | Reply Comment of PMRCL/DMRC |
|---|---|---|
| (6 Borrow material for Embankment | 2) If any other borrow material is to be considered as an alternative, for the high embankment, such as excavated material from tunnelling operations, which is all Clayey silt (CL-ML or CI material), suitability of this material has to be ascertained prior to using as structural fill material. The borrow material thus used, should be compactable to 95% MDD and should not cause differential settlement/adverse subsurface conditions that may damage to structure foundations. | —Suitability of any borrow material will be ascertained by contractor's DDC based on RDSO guidelines for railway formation |
| (7) Flooding Condition | — | —The formation level of the depot (El. 50.3 m) has been finalised based on HFL = El. 48.7m .Adequate perimeter drainage connecting to the city drainage has been provided at depot. |

Source: JST

### 4) Disaster risk assessment basic design

#### a) [Recommendation] Countermeasure of rainwater flooding under climate change

**Flooding:** A countermeasure for flooding at the entrance of the underground station is raised doorway usually. PMRCL/DMRC planned 60cm raised up form footpath elevation. JST recommended the prevention method of flooding in the case of future climate change as the following report;

The following table shows outlines the flooding countermeasures used for entrances and exits of subways in Japan and Thailand. Using these countermeasures as references, it had planned to adopt stairs and frame barriers (as used in Bangkok and Singapore) as flooding countermeasures for Metro Manila Subway stations also.

Similar measures are planned for elevators, entrances, and exits, including elevating them to prevent flooding and installing a slope for those with disabilities.

**Table 5-35: Inundation Countermeasures for Subways in Japan and Thailand**

| | Tokyo Metro | Bangkok MRT |
|---|---|---|
| Countermeasure | At entrances and exits with a risk of inundation, stairs and frame barriers (35 cm × 2 tiers ＝ 70 cm) have been installed.<br>At entrances and exits of stations at low elevations east of the Sumida River, water sealing doors have also been installed. | Stairs and frame barriers (1 m) have been installed at stations with a risk of inundation.<br>The same countermeasures are utilized in Singapore. |
| Example | <br> | <br> |

Source: Tokyo Metro https://www.tokyometro.jp/safety/prevention/wind_flood/index.html
JST

Patna Metro has considered the raised floor level for each entrance of the underground station.

JST asked that how to decide on this raised height for each entrance of the underground station.

Entrances, elevators, and elevator sheds are required to have countermeasures against flooding while maintaining both convenience and accessibility during normal operation hours.

In principle, it is proposed to adopt a combination of raised entrance floor levels and flood barrier panels as are used in Japanese subways.

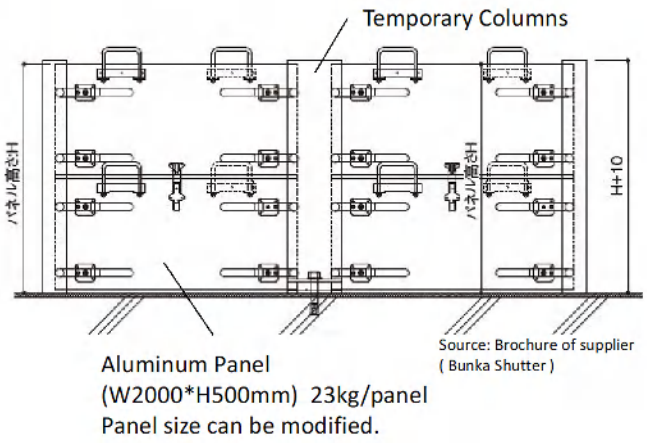


Floor Barrier Panels / Water-stop boards
(an example of Japanese underground station)

Source: Tokyo Metro
https://www.tokyometro.jp/safety/prevention/wind_flood/index.html

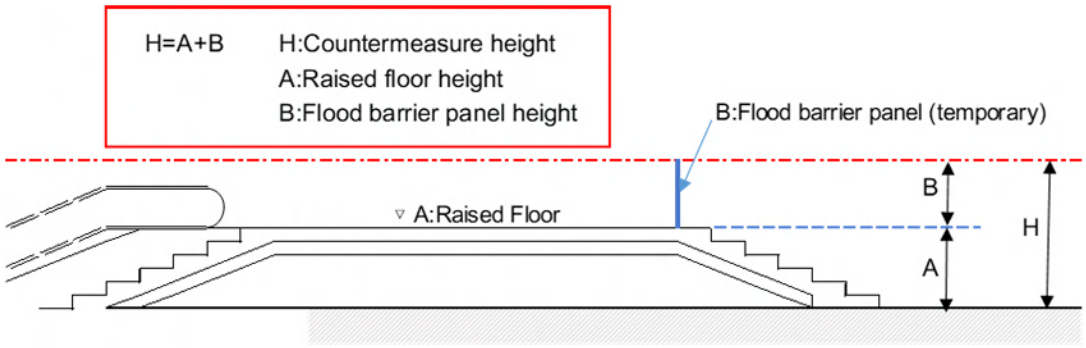
**Figure 5-81: Examples of Flood Countermeasures in Japan**

Although there are different types of flood barrier panels, those made of aluminum are recommended because they have the following benefits: they can be produced and installed up to a maximum panel height of 1.5 m; there shall be no restriction on the installation width; stepwise installation with multiple layers of panels is possible; panels are lightweight, and all components can be handled and installed by station staff members without difficulty; and finally, they are less expensive than other types of flood barrier panels.




Source: JST (Quoted from the catalog of a manufacturer)

**Figure 5-82: Examples of Flood Panel in Japan**




Source: JST

**Figure 5-83: Countermeasures for Flooding at Station Entrances**

**The below comment is replied from PMRCL/DMRC**

For the purpose of design of entry/ exit structures, including lifts and escalators the following criteria has been followed:

If the Highest Flood Level (HFL) is below road level, the plinth level of the entry/ exit structures will be taken as 600mm above road level.

Where HFL is above road level, the plinth level of the entry/ exit structures will be taken as 450 mm above HFL.

All other structures i.e. ancillary building, vents are designed such that there are no openings below the HFL.

This design criteria ensures there are no additional requirement of flood barriers.

b) **Earthquake**: Seismic design method is described in the Civil Engineering Design Specification. And there is no concern about liquefaction for the underground section because soil condition is mainly silt and clay

The below table shows the reply comment from PMRCL/DMRC for the seismic design method for each civil structure.

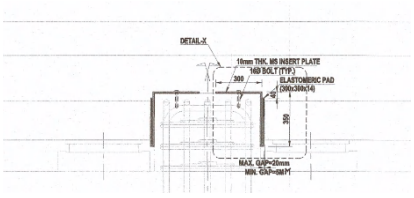
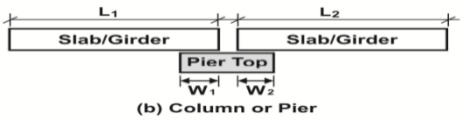
**Table 5-36: Seismic Design Method by PMRCL/DMRC for Civil Structures**

| Structure type | Seismic design method |
|---|---|
| Pier | Seismic design has been considered for Pier design as per the "Indian Railway Standard Code for Earthquake Resistant Design of Railway Bridges (Seismic Code) 2020" |
| Embankment at New Depot | Seismic design is considered for embankment as per literature paper for "Earthquake Induced Soil Pressures on Structures" as mentioned in Outline Design Specifications |
| Retaining wall at Ramp section | Seismic design is considered for retaining wall as per literature paper for "Earthquake Induced Soil Pressures on Structures" as mentioned in Outline Design Specifications. |
| Underground structure such as , U-Type retaining wall at Ramp section, Shaft, Box Culvert and Cross passage, | Seismic design is considered for underground structure as per literature paper on "Seismic Design and Analysis of Underground Structures" by Hashash et el as mentioned in Outline Design Specifications. |
| TBM lining (RC-Segment), | Seismic design is considered as per literature paper "Seismic Design and Analysis of Underground Structures" by Hashash et el. which is worldwide accepted method for TBM lining. |

Source: JST

The below table shows reply comment from PMRCL/DMRC for the seismic counter measure for each civil structure.

**Table 5-37: Seismic Counter Measure Method for Civil structures**

| Structure type | Purpose of seismic counter measure | Seismic countermeasure method by PMRCL/DMRC |
|---|---|---|
| Bearing | Superimposing rubber and steel plates in a sandwich-like shape, it has the effect of following the movement of the girder and reducing the seismic force.<br>However, if earthquake displacement of this system is large than allowable rail track displacement then it is necessary to stopper the system. | Seismic arrester has been provided with 10mm thick insert plate & 14mm thick elastomeric pad.<br> |
| Girder Connection | A bridge collapse prevention device, connects the two consecutive girders with the cable chain and prevents the girder from falling. | Seismic arrester has been provided to prevent from collapse. |
| Installation of displacement restricting structure | | Seismic arrester has been provided as displacement restricting structure. |
| Bridge Seating width | When the support is compromised, the girder falls onto the beam and stops the formation of a difference in level on the bridge. Increase the area of the beam top surface to prevent the girders from dropping. | Seating width has been provided as per the "Indian Railway Standard Code Bridge Rules": Reprint 2014<br><br>(b) Column or Pier |
| Displacement restriction device | When the bearing is compromised, the girder collapses onto the beam, impeding its ability to move and advance down the bridge. | Seismic arrester has been provided as displacement restricting structure. |

Source: JST

### 5) Restrictions on Civil design

JST has confirmed with PMRCL/ DMRC about the clearance between the existing road and viaduct of Patna Metro. In the basic design drawing is designed for minimum 5.5m

## (2) Construction

### 1) Substructure of Viaduct Section

The contractor should conduct test boring to check the depth of bearing strata before the main pilling works. The contractor executes pilling works with pilling machines, mobile cranes, and excavators within construction barricades. These machines are available without difficulty in India.

The contractor may carry the concrete from batcher plants located remotely. Concrete pouring into a bored hole should be through the proper size of tremie pipes. The contractor should plan well the concrete movement considering the time required against local traffic at each time.

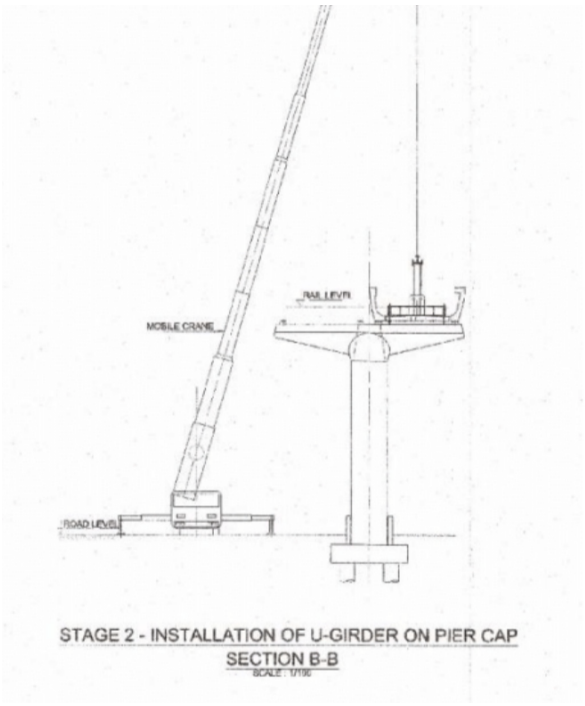
The contractor should remove the poor mixture section at the pile head before starting the footing structure. The contractor may use sheet piles to excavate for footing works due to the silty ground in Patna.

### 2) Superstructure of Viaduct Section

The contractor will make pieces of superstructures of the viaduct and station except for the pillar at the casting yard, minimizing the workload at the site. The shape of the superstructure is similar to many other metro projects in India. The contractor pre-casts the superstructure with steel molds. These pre-casting activities help streamline quality management.

The movement of pre-casted superstructures from the casting yard to the site may hamper the local traffic flow due to its speed and size. Therefore, the contractor has to plan the logistics activities at night or early morning, when the traffic volume is relatively low. In Patna, since the width of some roads is narrow, the contractor should study to decide the route from the casting yard designated by PMRCL in advance.

The contractor deploys mobile cranes to erect pieces of superstructures at the site. Actual erecting activities will happen at night as the mobile cranes should stand safety position by expanding outriggers while blocking some road lanes.




Source: PMRCL's Tender Document for PC-01

**Figure 5-84: Erection of Superstructure Using a Mobile Crane**

PMCRL renders casting yards to each civil contractor. JST visited two casting yards for PC-01 and PC-04 Contractors. The area for both sites is sufficient for pre-casting works. Yet, the nature of land differs as below. PMCRL will take responsibility for getting consent to set up a concrete batching plant from the Bihar Pollution Control Board.

**Table 5-38: Outline of Casting Yard**

| | PC-01 | PC-04 |
|---|---|---|
| Location | Eastern farmer's land along NH30 through public procurement | Government land inside the major bank of the Ganga River |
| Area | 14 acres | 12 acres |
| Accessibility | Excellent. Next to NH30 | Need to build a temporary road to a wide road on the bank |
| Fee | 900,000 Rs. per month | free |
| Others | N/A | Needs for measures against flood |

Source: JST

The PC-01 Contractor has established its casting yard, as shown in the photos below. The capacity of the concrete batching plant is 90 cubic meters per hour in total. The contractor operates it for 24 hours per day with two shifts. PMRCL will arrange a casting yard for PC-05 and 06 (underground civil portions under the JICA fund), where the contractors can establish TBM segment plants.



Source: JST

**Figure 5-85: Casting Yard for PC-01 Contractor along NH30**

### 3) Underground Structure (Cut and Cover)

The Cut and Cover works seem more straightforward than TBM, and non-experienced contractors among Joint Ventures might take responsibility for it. However, the contractor should ponder its detailed scheme based on the surrounding conditions, ground & water, proximity buildings, utilities, and local traffic because the underground earth (silty soil) will not stand like a rock, and it may get weak and distorted by heavy rain to potentially lead to some critical accidents at the site.

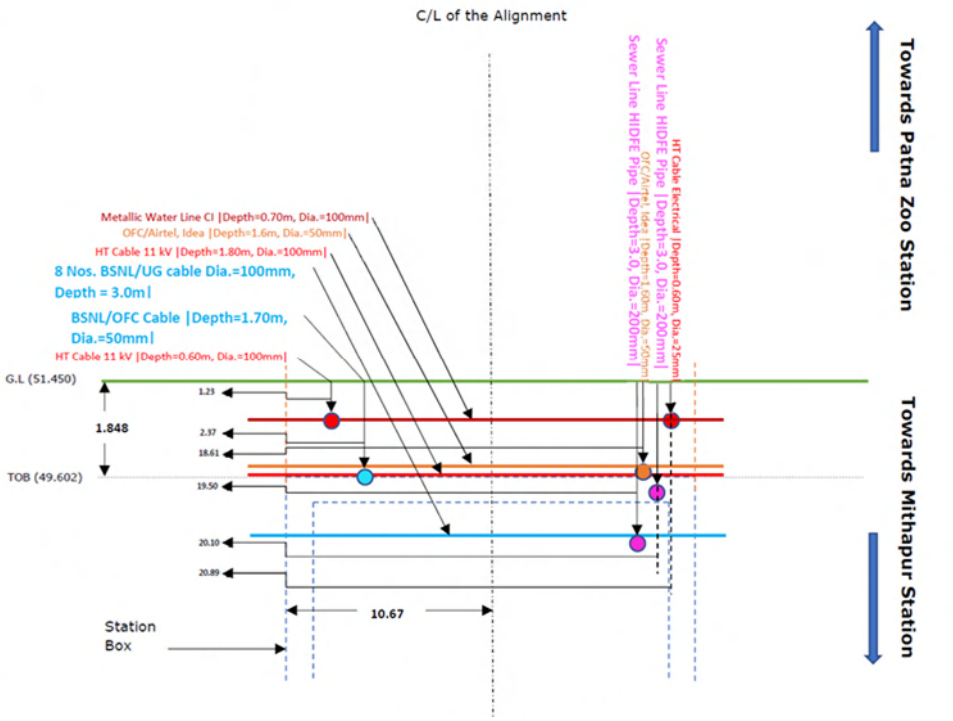
The Cut and Cover sites on Corridor 1 do not have sufficient construction areas, unlike many cities in India. The contractor should prepare to manage a robust logistics plan to bring construction materials and discharge muck and debris not to hamper the construction progress. DPR demonstrates the traffic diversion plan. Where a road width is less than 32 meters, the contractor builds one side of a station box first by blocking traffic on the other side and switches the side after construction is completed on the first side. However, as this sequence will take more time and cost, the contractor may want to utilize the temporary steel deck over the footprint of stations and entry/exit to balance construction efficiency with mitigation against the local traffic.

Regarding buried utilities, the contractor should divert some utility lines outside the station footprint or toward another road as the station box's top level is 1.5 meters at the minimum below the ground surface. In such a case, the contractor may need to manage areas beyond the station boxes and entries/exits. The sample of existing utilities located below 1.5 meters is as follows.

- Water pipe, 300 mm diameter, GL-1.8 m.
- BSNL/ OFC, 50 mm diameter, GL- 3.0 m
- Airtel/ OFC, 50 mm diameter, GL- 2.0 m
- HT (E) 11 kV, 100 mm diameter, GL- 1.8 m
- Sewer RCC, 900 mm diameter, GL - 2.4 m
- Gas, 200 mm diameter, GL -1.8 m

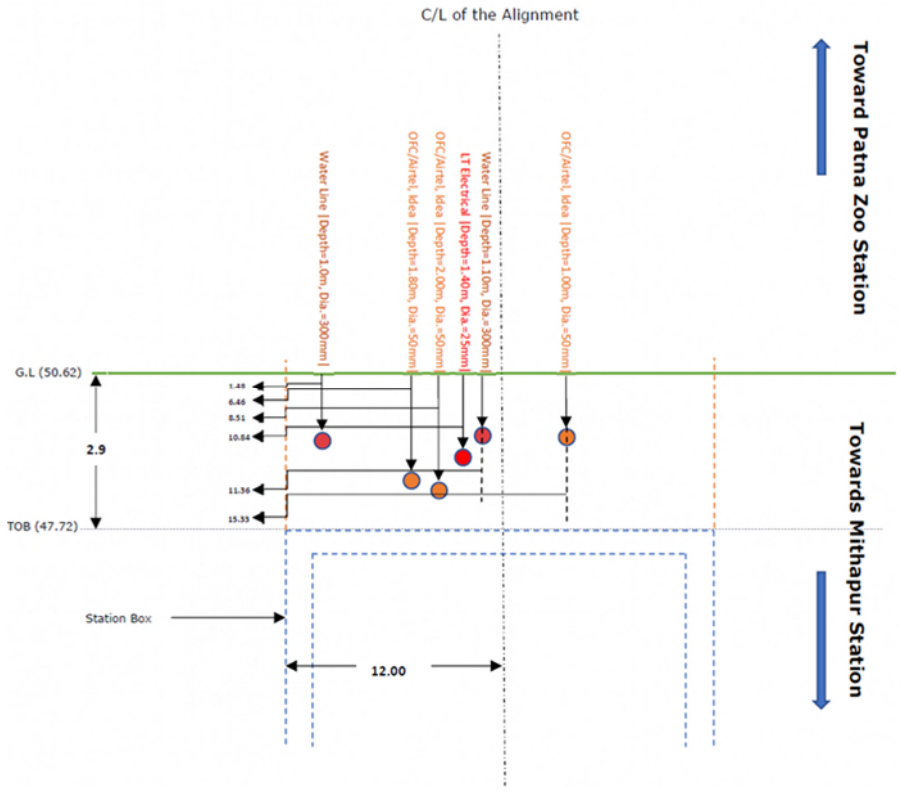
By the way, the utility identification drawings look over-sophisticated, connecting all lines throughout the alignment. The contractor should check the existence of uncharted utilities by test digging first.

The following section diagrams depict the relationship between utility lines and the station top slab in two typical stations. At Patna Junction, the contractor should divert several utility lines due to the shallow top slab. On the other hand, the contractor will not need to shift but suspend utilities at Vidyut Bhawan as the utility levels are shallower than the top slab.




Source: JST

**Figure 5-86: U/G Utility Lines at Patna Junction Station**




Source: JST

**Figure 5-87: U/G Utility Lines at Vidyut Bhawan Station**

### 4) Underground Structure (TBM)

The Corridor 1 has less access to open spaces to launch TBMs, while Corridor 2 has sufficient land. The contractors for Corridor 1 will need to manage on-demand construction transportation like in Tokyo and Singapore within the limited working area. PMRCL will allocate the casting yard and the muck disposal site dedicatedly to the individual contractors.

TBM's cutter bit and its alignment on the face should be customized to the silty ground even if the contractor utilizes second-hand machines. Otherwise, TBM might be stuck since it cannot scratch the earth as loosened silty soil fills gaps of cutter bits.

Based on the ground condition, TBM is expected to proceed at an average pace of 250 meters per month. With the figure, the number of TBM required for PC-05 and PC-06 to meet the construction period (42 months) will be at least three and two, respectively[35]. Two hundred fifty meters per month means that one TBM generates muck of over 300 cubic meters per day, which needs 100 dumping lorries to carry out from the launching shaft (where two TBMs usually work). Unless the Contractor maintains enough coordination with the local traffic authority, the traffic regulation (not but TBM system capacity) defines the TBM progress. That happened in Mumbai at the early stage until the contractor found the meeting points with the traffic police partly because the concerned persons could hardly envisage the effect of TBM works and balanced solutions since it was the first underground metro project in the city. To maintain the TBM progress requires a non-pure engineering aspect too.

[35] Please see Attachment 6-Construction Speed and Required TBM Units for the detailed calculation.

The contractor should deploy sufficient capacity of ancillary facilities with a backup system. A generator is one of the most crucial facilities in terms of work progress and safety and should always be on standby. Besides, the contractor should store spare parts and lubricant at the site.

The contractor should pay close attention to breaking retaining walls, passing potentially affected existing structures/buildings, and cross-passage construction. Especially in cross-passage construction, the contractor, with its detailed designer, should analyze the deformation of the ground and segment rings to plan the supporting works like bracing inside of segment rings and earth treatment (grout injection) in advance.

For quality and maintenance management, the contractor should seal or paint the lot number on each segment lining to secure traceability.

### 5) Protection of Proximity structures

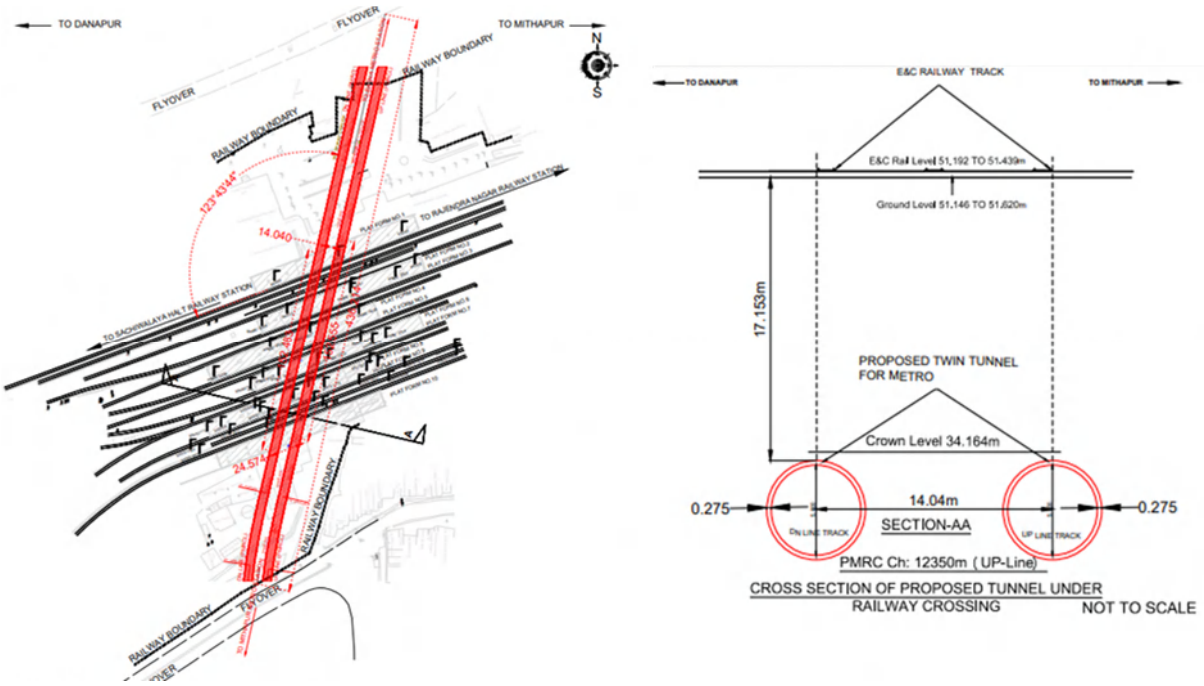
There are three types of proximity structures to be checked in the Patna Metro Rail Construction Project: (i) live railway lines, (ii) piles of existing superstructures along roads, and (iii) private/government land buildings.

(i) Live railway lines: the alignment of TBM passes the live railway lines between Patliputra and Rukanpura and near Patna Junction and Rajendra Nagar. The most extended section to underpass is at Patna Railway station, which will be nearly 150 meters long. PMRCL negotiated with East-Central Railway to get approval to pass TBMs. Due to the clearance between railway tracks and TBM (15-17 meters in the silty ground), a significant adverse impact may not cause. However, the Contractor should monitor rail level per the agreement with the Railway.



Source: JST

**Figure 5-88: Railway Lines at Patna Railway Station**




Source: PMRCL

**Figure 5-89: Live Railway Lines Crossing at Patna Railway Station**
Plan (Left hand side) and Section (Right hand side)

(ii) Piles of existing superstructures along roads: Patna City has many elevated roads and junctions. Those structures should have material pile foundations in the silty ground. The contractor should take care of the existing structures in the affecting zone, irrespective of TBM works or Cut and Cover works. The contractor, with its detailed designer, should estimate physical conflict and negative causation during construction activities to take proper engineering measures if needed. Samples of possible actions are enforcing the retaining wall to mitigate the relaxation of the ground backside of the wall and upgrading the segment lining to bear the load from the existing superstructures.

(iii) Private/government land buildings: Most buildings on the private and government land under which TBM will pass are low-rise buildings and the envisaged to have masonry foundations. Such lightweight structures will not cause additional loads to underground structures. Nevertheless, a building itself may be vulnerable to even minor ground deformation. The contractor should conduct a building condition survey along the alignment at the beginning. Depending on the survey result, they might need to claim a change of alignment or demolition of affected buildings to PMRCL. By the way, the ongoing underground civil contract (PC-03) contractually instructs, under the Key Date Schedule, the Contractor to proceed with the building condition survey soon after the Letter of Acceptance (before signing the contract) to shorten the construction period. The same condition will come to JICA civil portion to achieve the challenging timeline, which should be explicitly described in the bidding documents.

### 6) Construction under Private Land

Based on the building condition survey, the contractor, with its detailed designer, should establish a protection plan against vulnerable buildings and monitoring methods.

The contractor should monitor the level (height) of the ground above the TBM alignment, including an affected zone. Adverse effects may happen when the contractor over or under-execute activities like poor TBM face pressure management, over-excavation, and failing to inject gaps between earth and linings. The contractor has to take more care of its sequential actions in the sensitive zone at a slower TBM speed.

### 7) Traffic diversion and traffic safety during construction

Overall, stations, excluding Khemni Chak, on NH30 and associated service roads, have sufficient spaces for elevated metro construction. The contractor may temporarily expand the barricade at night when erecting superstructures with mobile cranes. During barricade expansion, the contractor should deploy sufficient light for vehicle drivers to identify the road space.




Source: JST

**Figure 5-90: Barricade Installation on NH30**

Khemni Chak is an integrated station of the Corridor 1 & 2 and aligned at almost the entire width of NH30. The contractor will block lanes following pilling works of the station structures. Once the pier works finish, the contractor blocks the lane between the piers to build station slabs. Lastly, the contractor blocks side roads while making entries/exits. The location of barricades varies in line with the construction sequence. The contractor should harmonize its works across the station to avert “zig-zag” traffic flow.

The Corridor 1 elevated section and underground stations are located on/under wider roads than the Corridor 2. Except for Danapur and Patna Junction, the contractor will not need to consider regional detours to maintain local traffic and can keep using three to four lanes for construction activities. For underground stations, in addition to three to four lanes blocking, the contractor may install a temporary steel deck for local feeder traffic, under which the contractor builds underground structures.

Some underground stations of Corridor 2 like Akashuvani, PMCH, and University are located under or next to narrow roads. That may provide only one-way traffic with a regional detour. Besides, Rajendra Nagar is aligned under a busy four-lane road near an overpass road bridge. The contractor should

negotiate with East-Central Railway to temporarily utilize the railway land for traffic diversion.

The contractor needs to install supplemental sign boards and blinking lights on the barricades at night. Furthermore, in case drivers' vision might be hampered at the connection to feeder roads due to barricades, the contractor may need to half the height of the barricade at the corner.

PMRCL agreed to utilize JICA Standard Safety Specification (JSSS), whose Sub-provision 2.2.2 Working Area Perimeter refers to fencing to prevent access to the site by unauthorized persons, which is a common instruction from many employers. However, JST observed that the number of security personnel was lacking, and the construction area was relatively open to the public. PMRCL may want to assign more security personnel to the Site to avoid any incidences involving a third party.

### 8) Special construction methodology

#### a) Low headroom piling machine

The construction methodology deployed in the project is not unique except for piling work with low headroom in Patna Junction. The footprint of the station box reaches the elevated highway, and the contractor should use a low headroom pilling machine under the elevated road to install retaining walls. Through an interview with DMRC and PC-03 Contractor, the nationally leading construction company, JST found that such a pilling machine is NOT commonly available in India.

PMRCL might consider shifting the station location to the north to avoid using such a unique machine. Nevertheless, maintaining the required track layout for two corridors after the shift is pretty challenging since Patna Junction is a longitudinally long station to include a switch-back section for Corridor 2. PC-05 Contractor will need to import a low headroom piling machine.




Source: JST

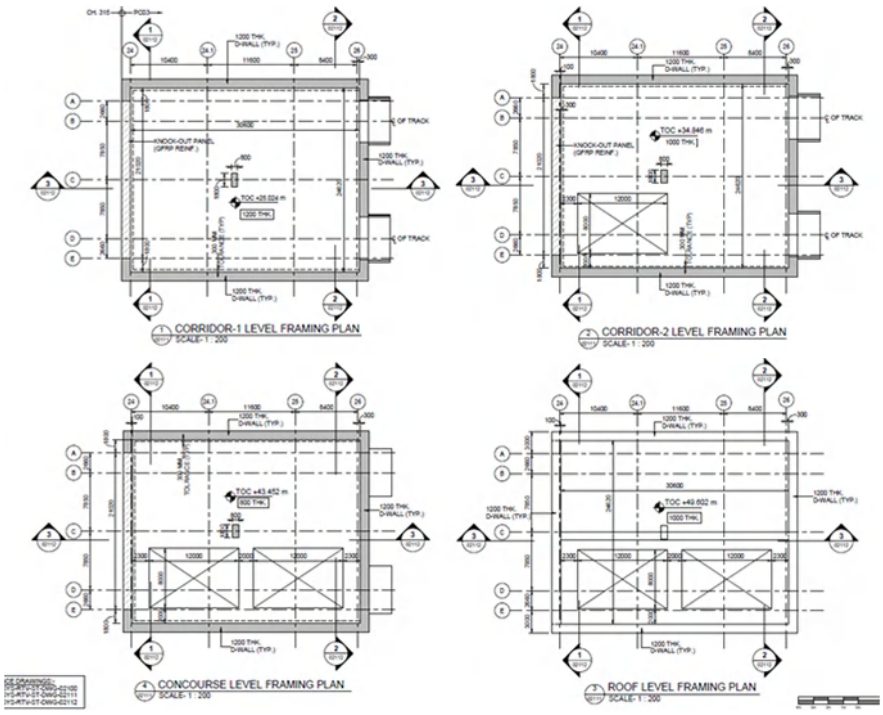
**Figure 5-91: Elevated Road above Station Footprint at Patna Junction**

#### b) Integrated underground station

Patna Junction is an integrated underground station, where TBMs of Corridor 1 reach the bottom after TBMs of Corridor 2 are retrieved at the middle level. The Corridor 2 Contractor has already started its

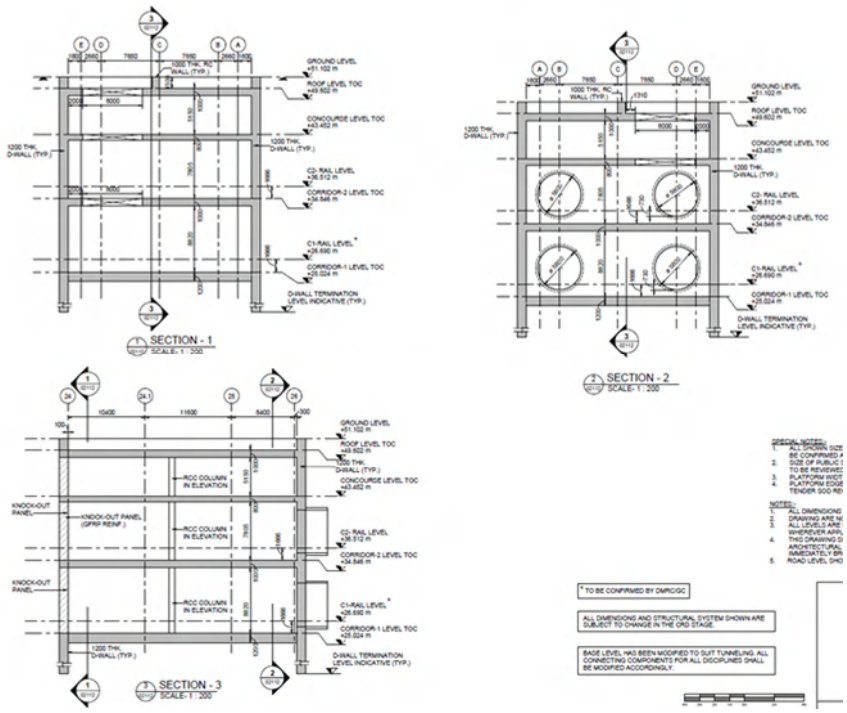
construction, and its TBMs will reach the station earlier than Corridor 1, while the Corridor 1 Contractor will build the station main box. PMRCL should settle many coordination issues like timeline, temporary facility, and workspaces before the physical interface.

PMRCL provided a solution to the interface, where the Corridor 2 Contractor builds the retrieval shaft next to the station box. The construction sequence is as follows. First, they retrieve their TBMs at the middle level. Next, they build the complete retrieval shaft until the bottom to render it for the Corridor 1 Contractor to recover their TBMs. Finally, the Corridor 1 Contractor breaks the temporary wall next to the station box. This scheme will work to solve the time difference between the two entities.




Source PMRCL

**Figure 5-92: Plan Drawings of Retrieval Shaft next to Patna Junction**




Source PMRCL

**Figure 5-93: Section Drawings of Retrieval Shaft next to Patna Junction**

c) TBM tunnelling with minor clearance

The internal diameter of the TBM tunnel is at least 5.8 meters, and the external diameter can be 6.45 meters. Whereas TBMs run by two contractors get near one another by less than 3.5 meters at the point of the retrieval shaft of Patna Junction as mentioned in the previous sub-section. Insufficient clearance in silty earth will skew earth pressure loading on the TBM lining. Some portions of the lining should bear additional stress. Worse, the second TBM running gets soil loosened by the first TBM passing exposed to dropping, which can lead to extra load on the TBM lining and significant subsidence of the ground surface.

Two contractors from PC-03 and 05 should take responsibility for bringing engineering solutions to these risks. Appendix 20 of the Employer's Requirements of the PC-03 Contract describes the responsibility of respective contractors where each contractor, with its detailed designer, conducts design analysis for both sides of structures following the construction sequence. The PC-03 Contractor running the first TBM should share this information with the PC-05 Contractor. On the other hand, The PC-05 Contractor should verify the analysis by the PC-03 Contractor and monitor their TBM tunnels while proceeding with its TBMs. This collaborative approach will work practically, and the bidding documents of PC-05 should enclose the exact requirement.

# 6. Station Planning

## 6.1 Overview of Existing Studies

### 6.1.1 Outline of Station Planning

The outline of the station planning is shown in the table below.

**Table 6-1: Corridor-1 Stations**

| Station No. | Station Name | Location | Elevated /Under Ground | Platform Type | Alignment |
|---|---|---|---|---|---|
| 01 | Danapur | Above of Saguna -Danapur Main Rd | Elevated | Side | Straight |
| 02 | Saguna Mor | Above of Beiley Rd | Elevated | Side | Straight |
| 03 | R.P.S. Mor | Above of Beiley Rd | Elevated | Side | Straight |
| 04 | Patliputra | Above of Beiley Rd | Elevated | Side | Straight |
| 05 | Rukanpura | Underground of Beiley Rd | Underground | Centre | Straight |
| 06 | Raja bazar | Underground of Beiley Rd | Underground | Centre | Straight |
| 07 | Patna Zoo | Underground of Beiley Rd | Underground | Centre | Straight |
| 08 | Vikas Bhawan | Underground of Beiley Rd | Underground | Centre | Straight |
| 09 | Vidyut Bhawan | Underground of Beiley Rd | Underground | Centre | Straight |
| 10 | Patna Junction | Underground of Fraser Rd, Near IR Patna St., Front of Buddha park | Underground | Side+ Centre | Straight |
| 11 | Mithapur | Above of SHANTI MARKET BUS STAND Rd | Underground | Centre | Straight |
| 12 | Ramakrishna Nagar | North side of Bypass Rd | Elevated | Side | Straight |
| 13 | Jaganpura | North side of Bypass Rd | Elevated | Side | Straight |
| 14 | Khemni Chak | North side of Bypass Rd | Elevated | Side+ Centre | Straight |

Source: DPR

**Table 6-2: Corridor-2 Stations**

| Station No. | Station Name | Location | Elevated /Under Ground | Platform Type | Alignment |
|---|---|---|---|---|---|
| 01 | Patna Junction | Underground of Fraser Rd, Near IR Patna St., Front of Buddha park | Underground | Centre | Straight |
| 02 | Akashuvani | Underground of Fraser Rd | Underground | Centre | Straight |
| 03 | Gandhi maidan | Underground of Gandhi Maidan Rd, Front of Gandhi maidan park | Underground | Centre | Straight |
| 04 | PMCH | Underground of Ashok Rajpath Rd | Underground | Centre | Straight |
| 05 | University | Underground of Ashok Rajpath Rd | Underground | Centre | Straight |
| 06 | Moin Ul Haq | Underground of Moin-ul-Haq stadium site | Underground | Centre | Straight |
| 07 | Rajendra Nagar | Underground of Kankarbagh Rd, Near IR Rajendra Nagar St. | Underground | Centre | Straight |
| 08 | Malahi Pakri | Above of Malahi pakari | Elevated | Side | Straight+Curve |
| 09 | Khemni Chak | North side of Bypass Rd | Elevated | Side+ Centre | Straight |
| 10 | Bhootnath | North side of Bypass Rd | Elevated | Side | Straight |
| 11 | Zero Mile | North side of Bypass Rd | Elevated | Side | Straight |
| 12 | New ISBT | Above Bairiya Rd, Near New Bus terminal | Elevated | Side | Straight+Curve |

Source: DPR

Elevated stations: Elevated stations are planned two types, Type 1 applies to all elevated stations except Khemni chak station, that has center type platform and two lanes. Type 2 applies has Khemni chak station that has four lanes and side and center type platform as transfer station.

**Table 6-3: Outline of Elevated Station Type**

| | Station Type | Typical Station Name | Station building length | Station Building Width |
|---|---|---|---|---|
| Type 1 | Elevated | All station excepted Khemni chak | 141.7m | 21.17m |
| Type 2 | Elevated | Khemni chak | 141.7m | 42.17m |

Source: DPR

Underground stations: 7 types with different number of Underground floor and station dimensions according to site conditions.

**Table 6-4: Outline of Underground Station Type**

| | Station Type | Typical Station Name | Underground Floors | Station building length | Station Building Width |
|---|---|---|---|---|---|
| Type 1 | Underground | Rajabazar, | 3 | 141.7m | 21.07m |
| Type 2 | Underground | Rukanpura,<br>Patna University Vikash Bhawan | 2 | 162.4m | 24.22m |
| Type 3 | Underground | PMCH | 2 | 227.4m | 21.07m |
| Type 4 | Underground | Gandhi Maidan,<br>Moin-U-Ihaq Stadium | 2 | 204.4m | 24.22m |
| Type 5 | Underground | Akashvani | 2 | 237.4m | 21.07m |
| Type 6 | Underground | Patna Junction | 3 | 347.4m | 23.42m |
| Type 7 | Underground | Patna Zoo | 2 | 356.4m | 21.07m |

Source: DPR

### 6.1.2 Outline of Station Design Criteria

The next table summarizes the basic features of a typical station.

**Table 6-5: Outline of Station Design Criteria**

| | |
|---|---|
| **Length of Platform** | Elevated Stations : 140.0m<br>Underground Stations : 140.0m |
| **Rolling Stock Composition** | 3/ 6 cars |
| **Cargo width** | 2,900mm |
| **Required Vertical Clearance** | Minimum vertical clearance between the Concourse and the road: 5.5m |
| **Platform Width** | (Elevated Section: Side platform)<br>Minimum 21.17m-wide proposed<br>(Underground Section: Island platform)<br>Minimum 21.07m-wide proposed<br>The width of the platform is determined by the number of passengers demanded during peak hours. |
| **Platform Screen Doors** | PSD Installation is not mentioned. |
| **Stairs, Escalators and Lifts for Normal and Emergency Operations** | The specification shall comply with relevant sections of NBC 2016 Part 4 'Fire & Life Safety' & Annexure J (including amendment 1 issued in March 2021) |

Source: DPR

## 6.2 Reviews of Existing Studies and Proposals for Improvement

Station Tender or Basic drawings and design reports have already been prepared by PMRCL for all stations on corridor 1 and 2. A review was conducted the station planning described in the received DPR, drawing and design repots. In this chapter 6, comments and recommendations for the future developing of basic and detail design phase are mentioned for improvement.

24 stations of Corridor-1 and 2 were reviewed to whether meeting with these criteria are as follows,

- Horizontal and vertical alignment, platform width and length following specifications
- The layout of stations in harmony with demand forecast and passenger flow
- Stairs, escalators and elevators have enough capacity for peak-hour passengers
- Facility layouts following station operation
- Safe fire emergency evacuation
- Adequate station plaza
- The convenience of passengers at transfer stations

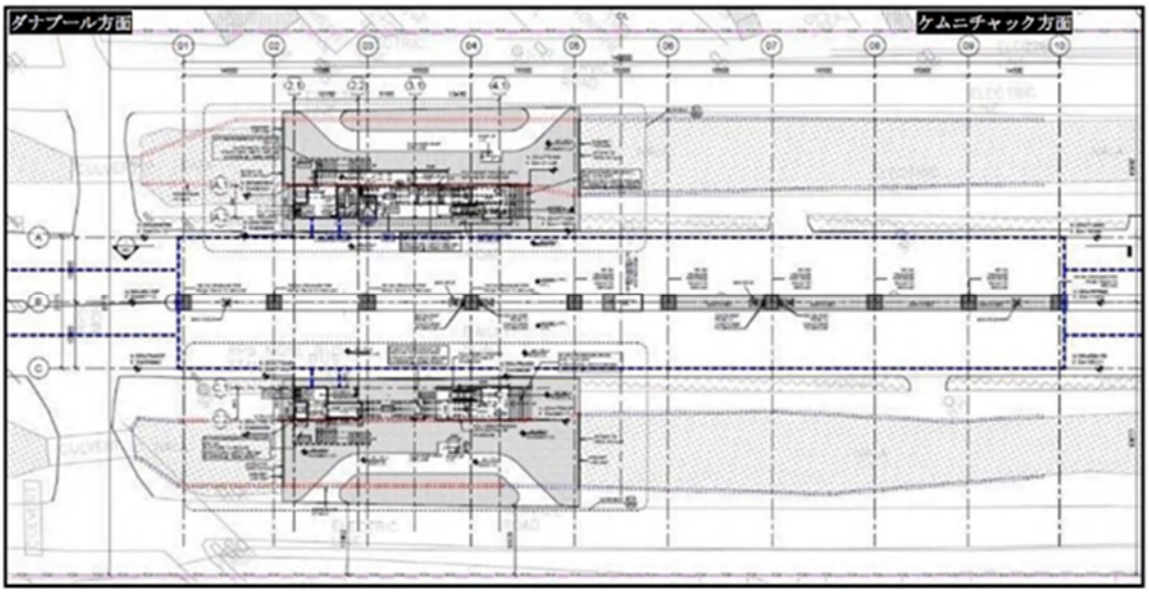
### 6.2.1 Location of Stations

Patna metro consists of 24 stations on two corridors with a total length of 31.448 km. The average distance between stations is approximately 1.367 km. Excluding Malahi Pakri and New ISBT underground station of corridor-2, most stations are located on the straight part of the alignment which makes it easier construction compared to the curved part of the alignment.

#### (1) Elevated Station

Basically, station location are planned on the median strip of the main road. Some elevated stations are planned to be located on the roadside or on the river parallel to the road depending on the surrounding conditions and the layout of the underground ramp connection.

In all cases, the footpaths on both sides of the road directly below or parallel to the station are connected to the station entrances and their associated footbridges. Therefore, that station users can access the station without having to cross the road. An example of an elevated station site layout is shown below.




Source: PCDD-01: Design Basis Report August 2022

**Figure 6-1: PRS MOR Elevated station site plan**

### (2) Underground Station

Most stations except Malahi Pakri underground station of Corridor 2 are located avoiding intersections. Therefore, the station location is less convenient than stations located at intersections. However, it is to be easier than stations located at intersections in construction work and traffic control during construction.

## 6.2.2 Facility of Stations

The plans for the station facilities were confirmed in the design report, which includes basic design drawing and station facilities design criteria. They are based on the applicable sections of the NBC 2016 Rail Facility Standards, and the station facility design criteria are based on the Delhi Metro example.

The review results and recommendations/remarks for each facility are provided below.

### (1) Station Structure

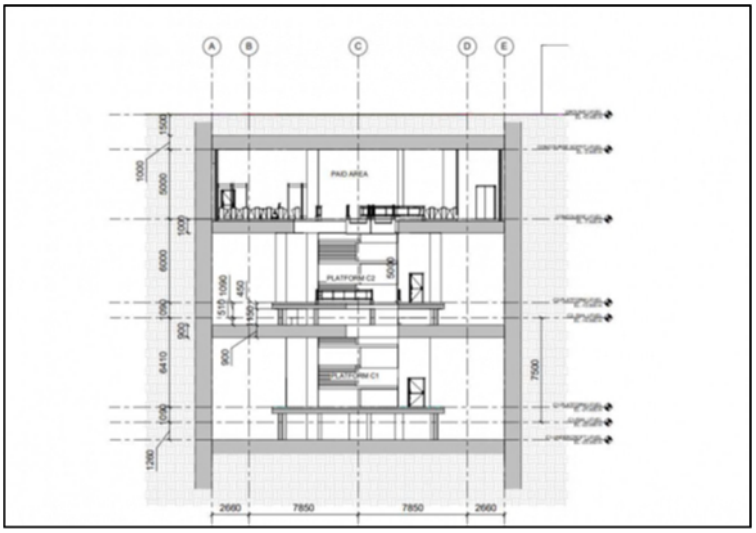
#### 1) Elevated stations

Station sizes and concourse formats are almost the same except for Khemni chak station. Therefore, passengers have few ways to recognize stations other than checking station name signs in the concourse from inside the train when outing the train, which may lead to the possibility of mistaking the station for the alighting station. It is recommended that the plan incorporate consideration to make it easier for passengers to recognize each station from inside the train by changing the color of the concourse interior at each station and by precisely arranging the station name signage.

#### 2) Underground station

The basic underground station is planned to have two layers with a concourse on the upper level and an island platform on the lower level with two tracks.

For some narrow underground sections and Patna Junction underground transfer station that included four tracks are divided three underground layers in order to reduce land acquisition and the extent of impact on the roadside.




Source: DPR

**Figure 6-2: Stack Platform type underground station section**

### (2) Platforms

According to DPR and the design report, the width of the platform will not be standardized, but will be at least 3m, and the width will be altered for each station according to the expected number of passengers. For stations with few passengers, the width should be reduced to reduce costs.

The platform edge dimension was confirmed in the corridor-1 design report and Contract drawing that is mentioned to match with the latest coach width 2,900mm included suitable clearance.

However, the corridor-2 platform dimension on provided tender drawing was planned to match with old coach width 3,200mm. Therefore, the platform edge location should be modified with the latest coach width 2,900mm on corridor-2 platform.

### (3) Platform Screen Door (PSD)

It is confirmed that there are not installed platform screen doors (PSD) to all stations in view of projected future passenger numbers and cost containment. The prevention of passengers falling from the platforms is to be monitored by CCTV or visually monitoring by station staff. For safety reasons, especially due to the risk of falls by visually impaired passengers, it is recommended that a post-installation type PSD be installed in the future if the PSD becomes necessary.

For future installation the PSD, Post-installation type PSD products should be considered and selected that are suitable for the station installation conditions. For example, platform end slab strength, Installation method, cargo door opening dimensions and construction period.



Smart home door®



Light weight type home door product

Source: Guidance for considering the introduction of new platform doors - from various development cases

**Figure 6-3: Products of Post-installation PSD**

### (4) Barrier-free design

Barrier-free measures in station facilities is designed in accordance with "Harmonised Guidelines and Space Standards for Barrier-Free Built Environment for persons with Disability and Elderly Persons in the year 2016" the barrier-free guidelines issued by the Ministry of Urban Development of India, and the Barrier-Free Standards for Station Facilities of the National Building Code of India (NBC2016).

The station facilities plan to be designed with consideration for persons with disabilities (physical, visual, hearing, internal diseases, etc.) in accordance with the guidelines and basic code that is confirmed in the Station Building design report.

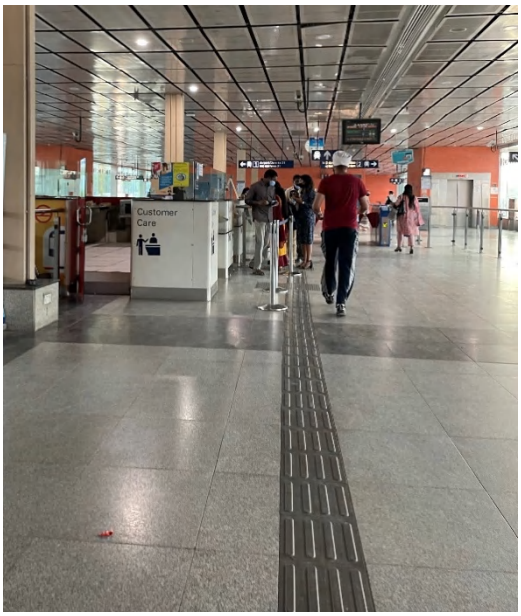
Table 6-6, the lists the design criteria for barrier-free design to be incorporated in the design of station facilities that is mentioned the Station Building design report.

**Table 6-6: Patna Metro Station Facility Barrier-Free Design Criteria**

| Facility | Criteria |
|---|---|
| Station Entrances and Exits | • The station entrance/exit should not have a difference in level. If a level difference is unavoidable, install a ramp or a ramp plus staircase.<br>• It is desirable that space be marked out near the station entrance/exit for vehicles carrying wheelchair users. |
| Reservation or Information Counters | • Reservation or information counters should have unobstructed approaches for wheelchair users.<br>• One counter height should be 750mm. |
| Concourse | • The concourse should not have a difference in level. If a level difference is unavoidable, install a ramp or a ramp plus staircase.<br>• The floor surface of a concourse should be made of non-slip material. At places, where the difference in level such as stairs, it is desirable that the appearance of the surface material be changed using color contrast.<br>• Install guiding blocks on the concourse for persons with impaired vision.<br>• Wherever columns exist, an electrical/ fiber-optic/ equivalent provisions shall be made keeping in mind the future of having revenue generating facilities as ATMS and also facilities for ease of passengers (coffee/ tea vending machines). |
| Staircase | For details, see the guidelines for staircases as per Part 4 'Fire & Life Safety' & Annexure J of NBC 2016 (including amendment 1 issued in March 2021). |
| Lifts (Elevators) | • Install a lift (elevator) to enable passengers with disabilities to move between floors.<br>• For the lift (elevator), install one warning block for persons with impaired vision 300 mm away from the call button. |

| Facility | Criteria |
|---|---|
| Toilets | Install a toilet and washstand suitable for use by wheelchair users and other passengers. |
| Ticket Gates | One of the ticket gates should have a continuous line of guiding tactile blocks for persons with impaired vision. |
| Platforms | • The platform should have one row of dotted guiding blocks for persons with impaired vision, 800 mm or more from the edge.<br>• The paved surface of the platform must be made with a non-slip material<br>• Stairs, kiosks and dustbins on the platform must not hinder the clear passage of persons with impaired vision and wheelchair users.<br>• A bench should be installed on the platform, having guiding block around it. |
| Rolling Stock (Car) doors | • Car doors should be wide enough for wheelchair users (minimum 900mm)<br>• The gap between car doors and the platform should be reduced to an absolute minimum. |
| Information | • The information board should be made easily readable by using sufficiently large text size, distinct contrast and illumination.<br>• It is desirable that in addition to a printed version of the train schedule, table of fares and other travel information also be in Braille. |

Source: PCDD-01: Design Basis Report April 2022




Source: JST

**Figure 6-4: Guide block installation example of Delhi Metro**

### (5) Gender and Infant considerations

It was confirmed from the tender drawings and questions and answers that the station facilities have the gender and infant considerations listed in Table 6-7. It is proposed that all stations should have a women's helpline desk staffed by women from the police or PMRCL security departments.

**Table 6-7: Patna Metro Station Facility Gender and Infant design consideration plan**

| Facility | Gender and Infant considerations |
|---|---|
| Toilet separated male and female | The toilets are to be installed for passengers and station staff in all station-paid concourse area. Moreover, gender-segregated toilets for station staff in some station back-office areas. |
| Transgender toilet | The transgender toilet is to be installed alongside passenger toilet areas in the concourse at some stations. Transgender people can use the toilets without having to worry about the stares of others which they felt when using the Male or Female toilets. |
| Diaper-changing tables | The diaper-changing table is to be installed in multi-purpose toilets of a part of some stations. By installing the table in multipurpose toilets that can be used by both men and women. |
| Separate security gates | Two lines of security gates to be installed at all stations that are planned as separate rows for men and women. In addition, a women's body search area is planned with a curtain to prevent women from being seen by others. |
| Platform | The platform is designed to have a good view and to eliminate blind spots, thereby preventing and controlling crime and allowing female passengers to use the platform safely. |

Source: JST




Multi and Transgender toilet



Diaper-changing tables

Source: JST

**Figure 6-5: Examples of accommodation of Gender and Infant considerations**

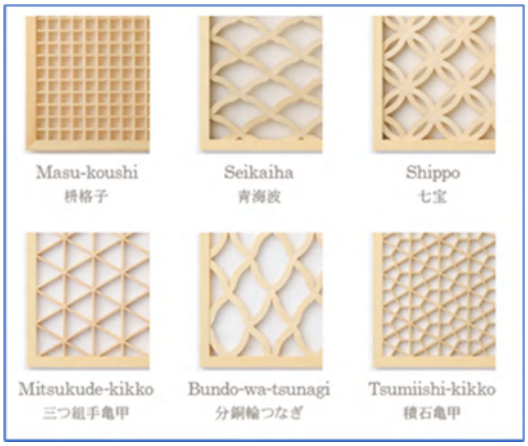
### (6) Station design proposals

In order to express friendship by incorporating the design of cultural links between Patna City and Japan into the station facilities and to express Patna City's appeal to station users through design, two proposals were proposed to PMRCL and one proposal was accepted into the Station design.

**1. Incorporate designs related to Buddhism, a common culture, into station interiors**

JST proposed to incorporate designs related to Buddhism as a common culture, into the interiors of the concourses and wall finishing of Patna Junction and Rajendra Nagar stations which are transfer stations to the national railway station.

The proposal is that included the incorporation of KUMIKO which was brought to Japan as a temple construction technique when Buddhism was introduced to Japan about 1,400 years ago, and the use of simple Buddhist icons in the station wall design. However, this proposal was rejected because of "Buddhist designs are already used in the Patna national railway station building and PMRCL considers to express local design of Patna other than Buddhism in this metro".




Souse: TANIHATA Co., Ltd. HP

**Figure 6-6: Design sample of ceiling and wall finishing design**

**2. Incorporate the design of the Bihar Museum, designed by a Japanese architect**

The proposal is to express the friendship between Patna City and Japan by using motifs or materials used in the design of the Bihar Museum, one of the landmarks in Bihar designed by a Japanese architect. PMRCL also considered the same proposal at the time of this study. The design plan incorporating this proposal will be used to external finishing of elevated station building and the exterior walls of the underground station entry and exits.

The exterior design plan incorporating this proposal is planned to express friendship between Patna City and Japan through the extensive use of latticework incorporating motifs used in the Bihar Museum fence. Moreover, the design effects are increasing transparency and harmonizing with the surrounding landscape.



Source: PCDD-01: Design Basis Report August 2022

**Figure 6-7: Station exterior design perspective**

### 6.2.3 Guideline for Evaluation of Emergency Evacuation

The station design adopts NBC 2016, Part 4 'Fire & Life Safety' & Annexure J (including amendment 1 issued in March 2021) and is being planned to meet the expected number of passengers during normal peak hours and to meet relevant requirements for emergency evacuation.

### 6.2.4 Interchange Stations

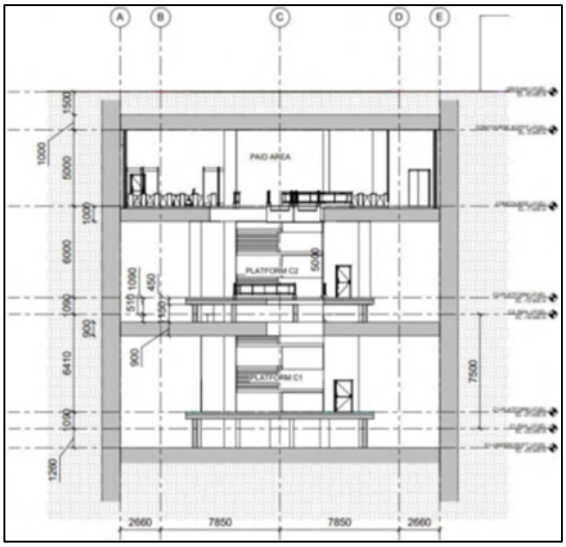
#### (1) Transfer Station between corridors 1 and 2

The two planned transfer stations for corridors 1 and 2 are the Patna Junction underground station and the Khemni Chak elevated station. The Patna Junction underground station will be connected to each corridor by a stack platform, while the Khemni Chak elevated station will be connected to each corridor by the parallel platform which makes it easier for passengers to transfer between the two corridors. The Khemni Chak elevated station is twice the width of the other elevated stations. It is possible that the evacuation route to be longer than at other stations. Therefore, evacuation safety should be validated.

**Table 6-8: Outline of Interchange Station**

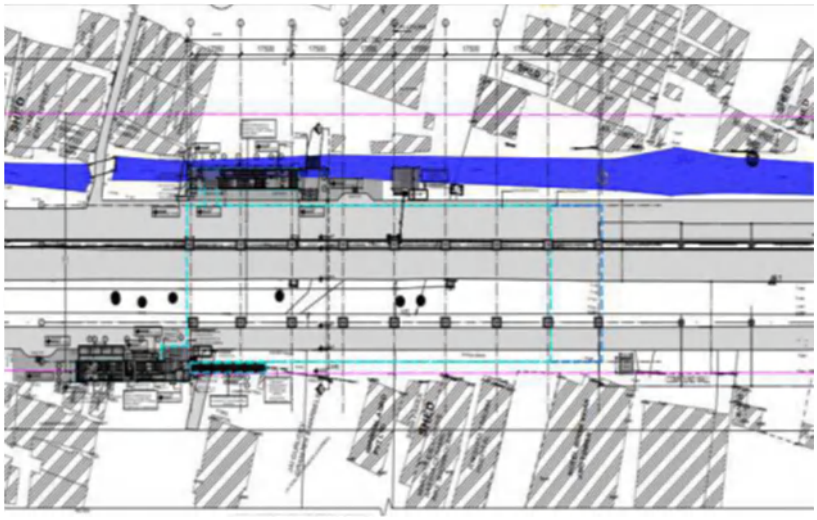
| Station name | Interchange corridor | Type |
|---|---|---|
| Patna Junction | Corridor-1, Underground | Stack Platform |
| | Corridor-2, Underground | |
| Khemni Chak | Corridor-1, Elevated | Parallel Platform |
| | Corridoe-2, Elevated | |

Source: DPR




Source: DPR

**Figure 6-8: Section Drawing: Patna Junction Interchange Station**



Source: DPR

**Figure 6-9: Site Plan Drawing: Khemni Chek Interchange Station**

### (2) Transfer Station with Indian Railways Station

There are two existing transfer stations with Indian Railways (IR).

Patna Junction Underground Station (Corridor 1 and 2) and Rajendra Nagar Underground Station (Corridor 2).

Patna Junction underground station is located to the north side of the IR Patna station that is planned to be connected to the IR Patna station plaza by an underpass.

Similarly, Rajendra Nagar station is planned to be connected to the station plaza of IR Rajendra Nagar station through an underpass. These are allowing passengers to reach the station plaza without crossing the road on the ground.

However, since both stations have only one underpass connect to the IR Station plaza, the underpass width should be adjusted to meet the expected future demand for transfers. In addition, the redevelopment of the

plaza in front of the IR Patna station is planned for Patna Junction station in the future, the layout of entrances and exits should be carefully coordinated with the redevelopment plan so as not to impair the convenience of transfers.

## 6.2.5 Disaster control

### (1) Flood control measure

In the Basic design, the subway entranced is planed that raised 450mm above the level of the sidewalk above ground to prevent water from flowing into the underground station in case of flooding. However, considering the expected increase in the number of cyclones and typhoons caused by global warming and the occurrence of torrential rains, it is recommended that watertight panels be installed at the station entrances to further prevent water inflow during flooding.

### (2) Anti- earthquake measures

There was no major damage to buildings due to previous earthquakes in Patna City which has been confirmed. The following measures plan to prepare for the expected earthquake level are confirmed.

**Underground stations**

The underground station is planned seismic design for considering the interaction between the ground and the station structure and the effects of earthquakes. The shaking of underground structures is significantly damped by forces acting in the same direction as the ground. Therefore, the interior finishing of the underground station building is regarded as a secondary member that is not subject to seismic forces and Secondary members will be designed as the seismic forces affect is nothing to them. Therefore, separate seismic measures are not envisaged for the secondary components.

**Elevated stations**

The Elevated station is planned to be seismic design the same as underground stations, and no separate earthquake countermeasures are envisaged for the secondary member in terms of interior and exterior. However, some buildings in Patna City were damaged by the earthquake in the past that were felt off or falling off interior and exterior finishing materials.

Therefore, as additional safety measures, the following reinforcements are recommended to prevent the interior and exterior finishing materials from falling out.

- Providing anti-sway bars on ceiling frames
- Using Light weight ceiling
- Considering the angle of displacement between layers of exterior finishing installation.
- Prevent block walls from collapsing, ensure that small columns and lintels are properly positioned and fixed to the structure with reinforcement bars.
- Using fall prevention implement for station equipment

# 7. Inter-Modal Integration

## 7.1 Overview of Existing Studies

Generally, the metro system is incomplete without connectivity with existing public transport. Intermodal integration is crucial for the success of multimodal transport systems. Intermodal integration involves integrated public transit network planning, development of footpath and feeder networks, and development of intermodal stations to minimize delay/transfers, among others.

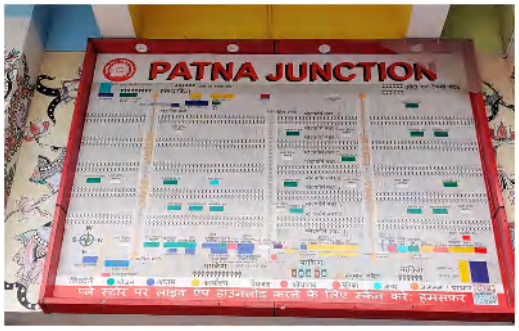
CMP2018 provides the proposal on bus rationalization and feeder service planning to enhance the connectivity between metro and existing public transport. The existing route network requires substantial modification to increase the catchment, and to connect with metro corridors and scheduling plan. There is an urgent requirement of a well-planned Bus Network & Bus Transport Facilities to cater to the metro system. The public transport strategy for Patna City is derived considering all the factors of the existing situation and the best possible reorganization factoring all components of an efficient and sustainable system. Not all the routes can operate buses but identified routes may operate these mini buses after removing encroachment and widening of roads along with newer metro and ring road development.

Feeder services are required to utilize the high capacity of the metro system and support high-frequency services in the main corridors. A feeder service can often provide a more frequent and useful local service and thus generate more local journeys if there is potential in the market. With high mode shift toward s E-rickshaw in Patna City, these can form basis of a feeder network for mass transit systems.

CMP2018 also pointed out that the connectivity of public transport may further improve with the integrated fare system which comprises single ticketing facility for all public transport modes.

In Metro Policy 2017, the integration of various modes in urban area is addressed. Integration between various modes like roadway, railways, non-motorized transport, and other modes of transport enhances the mobility of the citizens and encourages public transport. Existing railway suburban services or circular rail systems, if any, should be integrated with the metro rail and other transport modes. The various service providers must collaborate through the signing of a Memorandum of Understanding (MoU), to provide seamless integration between the various modes.

The following photos illustrate the situation in front of Patna Junction Railway Station that was observed by JST during the field survey in June 2022. The station plaza (shown as B and C) in front of the station is used for private car parking, which could be used for public transport connections. The roundabout beneath a flyover is used as un-organized bus stops and autorickshaw riding zones, which should be improved.




A. Layout of Patna Junction Railway Station with indications on parking area




B. Unorganized parking and traffic congestions in front of the station



C. Curent station front from another angle



D. Current station front from another angle

Source: JST

**Figure 7-1: Patna Junction Railway Station Front**

In comparison, the Bandra (W) Station in Mumbai is a good example of how regulation of Three-Wheelers and shift of feeder services can change the station front over the years.

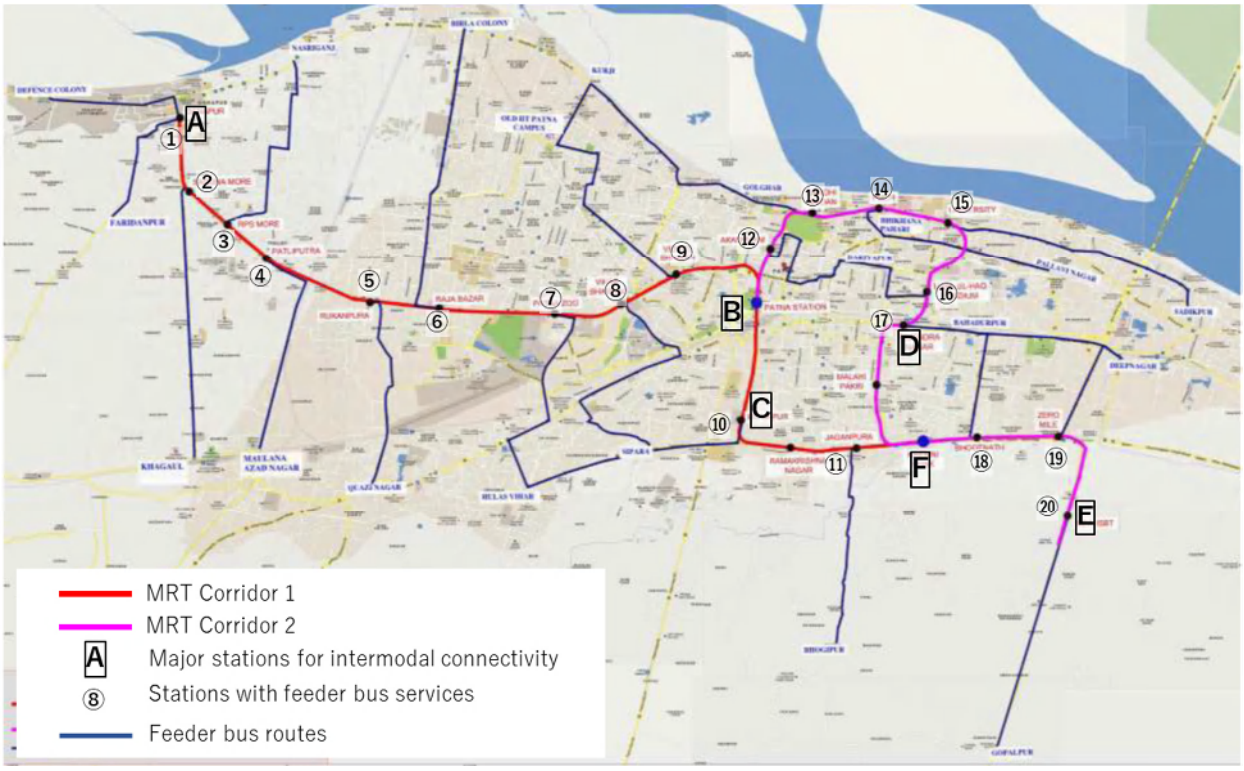
## 7.2 Reviews of Existing Studies and Proposals for Improvement

Regarding the integration of modes, DPR (Chapter 7) presents the following proposed measures to enhance connectivity between Metro and the existing public transport systems. The implementation of these policies should be secured by the Transport Department, Urban Development and Housing Department of the State Government of Bihar, PMRCL and relevant stakeholders.

**Table 7-1: Measures to Strengthen Connectivity between Metro and Existing Transport System (proposed in DPR)**

| Focal Items | Policy/ Actual Idea |
|---|---|
| Ensure the intermodal integration with existing systems | Presented sidewalk and elevator improvements around six major stations (Danapur, Patna St, Mithapur, Rajendra Nagar, ISBT and Khmni Chak– see the following figure and table) with rail and bus terminal connections, ensuring the connection with entrances, measures to relocate squatters, and preparing space for bus and cabs to board and alight. |
| Feeder service concept | 0.5 to 1 km on foot, but beyond that, policy to share by bus, bicycle, 3W, etc., with boarding and disembarking/connecting functions at each station. |
| Introduce a feeder buses system | Establish feeder bus service with a route length of 3 to 5 km at 20 of 25 stations in total– see the following figure and table for the 20 stations, operating every 6 to 20 minutes; estimated that 97 minibuses (35 seats) will be necessary for FY2041. |
| Introduce public share cycles | Estimated demand for a total of 1,700 units as of 2041 |
| Introduce the station surrounding facilities | Development of bus stops, car parking, bicycle parking, signages, etc. |
| Other measures for intermodal integration | Support for people with disability, barrier-free facilities, adjustment of operation schedule, consolidation/reduction of overlapping bus routes to avoid competition with Metro, fare coordination, provision of operation/transfer information and MaaS /ITS support, and organizational coordination to accelerate these efforts. |

Source: DPR




Source:DPR,JST

**Figure 7-2: Major 6 Stations for Intermodal Integration and 20 Stations with Feeder Bus Routes Plans**

**Table 7-2: List of Major 6 Stations for Intermodal Integration and 20 Stations with Feeder Bus Routes Plans**

| Major Six Stations for Intermodal Integration | Transport Modes to be Connected | Proposals for Stations with Feeder Bus Services | |
|---|---|---|---|
| | | Corridor 1 | Corridor2 |
| A) Danapur | Bus, IPT | ① Danapur | ⑫ Akashuvani |
| B) Patna Station | National Railway, Bus, IPT | ② Saguna Mor | ⑬ Gandhi maidan |
| C) Mithapur | Bus, IPT | ③ R.P.S. Mor | ⑭ PMCH |
| D) Rajendra Nagar | National Railway, Bus, IPT | ④ Patliputra | ⑮ University |
| E) New ISBT | Intercity bus, Bus, IPT | ⑤ Rukanpura | ⑯ Moin Ul Haq |
| F) Khemni Chak | IPT | ⑥ Raja bazar | ⑰ Rajendra Nagar |
| | IPT: Intermediate Public Transport services including taxi, share-rides, on-street parking section Kiss & Ride and off-street parking. | ⑦ Patna Zoo | ⑱ Bhootnath |
| | | ⑧ Vikas Bhawan | ⑲ Zero Mile |
| | | ⑨ Vidyut Bhawan | ⑳ New ISBT |
| | | ⑩ Mithapur | |
| | | ⑪ Jaganpura | |

Source: DPR, JST

The JST comments on those integration policies for the following:

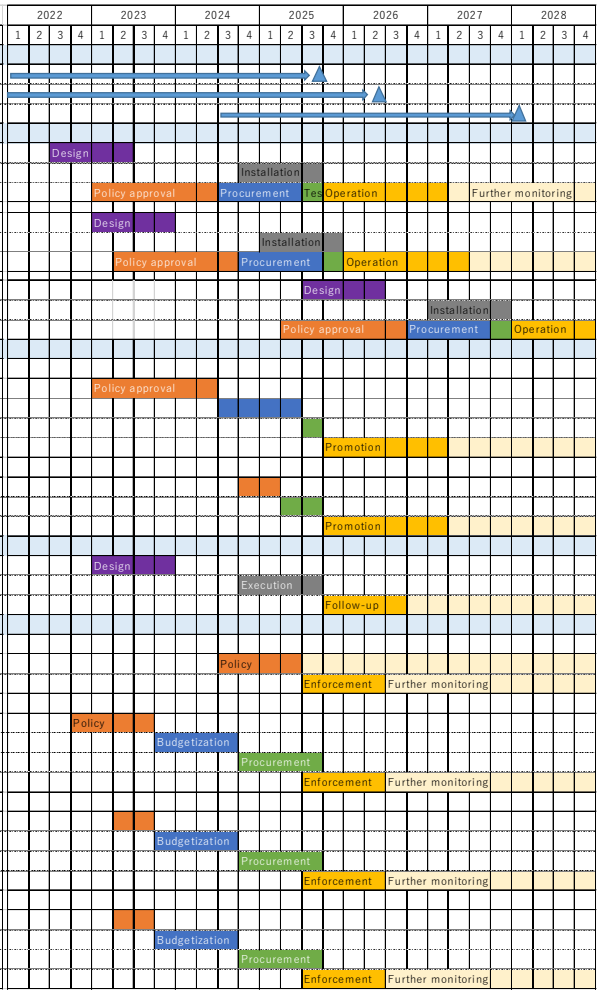
- The public share bicycle services will be valuable for a feeder, however, various types of share mobility and providers have been proposed recently. It is better not to stick to using the bicycle for sharing services.
- The fare integration in the DPR proposes payment media integration among various transport services.
- Physical improvement at and around the stations should be incorporated into the metro station construction contract, therefore, the design should be done in the station design process for materialization. These designs will require the approval of the Urban Development and Housing Department of the Bihar Government.
- The Transport Department of the Bihar Government should approve various transport service integration and rationalization. City Authority should be involved in the fare policy. Such policy approval requires unexpected time and difficulties with opposition groups and stakeholders.

JST proposes a roadmap of the intermodal integration policies in order to secure the implementation. The proposed roadmap has been discussed with PMRCL and obtained the acceptance from PMRCL. The roadmap shows the policy and steps for implementation, entities in charge, expected months, and depicted time schedules as bar charts. The time schedule for implementation steps was adjusted to the opening of the metro for the Corridor 2 Phase1. The barchart suggests the following:

- JST expects the planning stage for the feeder bus services for Corridor 2 Phase 1 should be started in the early months of 2023 to be ready for the metro opening.
- JST can suggest that policy development and arrangement of the smart ticketing must be started in 2022, otherwise the fare integration cannot be ready for the metro opening.
- This roadmap is assuming an ideal condition that PMRCL has the proper personnel and technical capacity to handle those policies.
- The integration policy should be flexible to the market and passenger demand. JST proposed a proper period of monitoring, revision and improvement procedure after the opening of the services.

## Table 7-3: A Roadmap for Intermodal Integration Policies (proposed by JST)

| Cat. | Items | Activities | Entities in Charge | Period |
|---|---|---|---|---|
| Expected event | | | | |
| | | Opening of Corridor 2 Phase1 (provisional) | NA | |
| | | Opening of Corridor 2 Phase2 (provisional) | NA | |
| | | Opening of Corridor 1 (provisional) | NA | |
| Physical Improvement at Major 6 stations | | | | |
| | | Design & Coordination for Corridor 2-P1 (ISBT, Khem Chak) | PMRCL/UDHD | 12 |
| | | Implementation of Corridor 2-P1 | PMRCL | 12 |
| | | Feeder bus coordination for corridor 2-P1 | PMRCL/DoT | 33 |
| | | Design & Coordination for Corridor 2-P2 (Raj Nag, Patna St.) | PMRCL/UDHD | 12 |
| | | Implementation of Corridor 2-P2 | PMRCL | 12 |
| | | Feeder bus coordination for corridor 2-P2 | PMRCL/DoT | 33 |
| | | Design & Coordination for Corridor 1 (Danapur, Mithapur) | PMRCL/UDHD | 12 |
| | | Implementation of Corridor 1 | PMRCL | 12 |
| | | Feeder bus coordination for corridor 1 | PMRCL/DoT | 33 |
| Feeder Service Provision | | | | |
| | Bus services (case for Corridor 2-1) | | | |
| | | DoT approval for New route re-organization | PMRCL/DoT | 18 |
| | | Employment and Procurement | PMRCL | 12 |
| | | Test run/System/Installation | PMRCL/Operator | 3 |
| | | Monitoring/Promotion | PMRCL/Operator | 18 |
| | Shared Mobility Services (case for Corridor 2-1) | | | |
| | | Planning/Design/Approval | PMRCL/DoT | 6 |
| | | Procurement/Installation | PMRCL | 6 |
| | | Monitoring/Operation/Promotion | PMRCL/Operator | 18 |
| Physical Infrastructure | | | | |
| | | Planning/Design/Approval | PMRCL/UDHD | 12 |
| | | Execution | PMRCL | 12 |
| | | Follow-up, coordination | PMRCL/UDHD | 12+ |
| General Coordination (case for Corridor 2-1) | | | | |
| | Operational Integration | | | |
| | | Route-coordination, Policy Development | PMRCL/DoT | 12+ |
| | | Enforcement and Moniroting | PMRCL/DoT | 12+ |
| | Fare Integration | | | |
| | | Smartcard ticketing policy confirmation | DoT/PMRCL/Regional Authority | 12 |
| | | Budget for bus/feeder services providers | DoT/PMRCL | 12 |
| | | Procurement and Installation / Monitoring | PMRCL/Operator | 12 |
| | | Monitoring, Assessment, and policy revision | DoT/PMRCL | 12+ |
| | Information integration | | | |
| | | Policy development and planning | DoT/PMRCL/City | 6 |
| | | Budget for implementation | DoT/PMRCL | 12 |
| | | Procurement and Installation | PMRCL/Operator | 12 |
| | | Monitoring, Assessment, and policy revision | DoT/PMRCL | 12+ |
| | Institutional Integration | | | |
| | | Policy development and planning | DoT/PMRCL/Regional Authority | 6 |
| | | Budget for implementation | DoT/PMRCL | 12 |
| | | Implementation | DoT/Regional Authority | 12 |
| | | Monitoring, Assessment, and policy revision | DoT/Regional Authority | 12+ |




Note: The partial opening timing of the Corridor 2 is provisional. The roadmap is to enhance early actions, therefore, this schedule is based on the PMRCL's opening schedule as shown in the chart. The partial opening should be monitored as it may change with political and economic situation.

Source: JST

# 8. Train Operation Plan

## 8.1 Overview of Existing Studies

### 8.1.1 Operation Philosophy

The basic policy of train operation is as follows.

1) The train intervals match demand with a few exceptions.
2) The operation meets the demand for passengers economically both for peak and off-peak hours.

### 8.1.2 Concept of Train Operation Plan

The concept of the train operation plan is as follows.

1) The train operation is 19 hours/day from 5:00 to 24:00, and the stopping time at the station is 20 - 30 seconds.
2) The time from 24:00 to 5:00 is secured for the maintenance for rolling stocks and facilities.
3) The margin time for the operation is 5 % of the total (including 8 % in coasting operation)
4) The scheduled speed is as follows.
   Corridor 1 (Danapur – Kemni Chak) : 35 km/h (Estimated value in DPR)
   Corridor 2 (Patna Station – New ISBT) : 35 km/h (Estimated value in DPR)
5) The time for turn-buck at end stations is as follows.
   Corridor 1 (Danapur – Kemni Chak) : 3 min. (Automatic turn-back without driver)
   Corridor 2 (Patna Station – New ISBT) : 3 min. (Automatic turn-back without driver)

### 8.1.3 Train Formation

The PMRCL assumes the following train formation.

1) Train formation
   - DMC : Driving Motor Car
   - MC : Motor Car
   - TC : Trailer Car
   - 3-car train set : DMC + TC + DMC
   - 6-car train set : DMC + TC + MC + MC + TC + DMC
2) Passenger capacity (@ 6 passengers per square meter of standee area)

   Car width 3.2m in DPR
   - DMC : 282 (42 seated + 240 standing)
   - MC/TC : 298 (50 seated + 248 standing)
   - 3-car train set : 862
   - 6-car train set : 1,756

   Car width 2.9m changed by PMRCL based on MOHUD guideline in July 2022
   - DMC : 252 (42 seated + 210 standing)

- MC/TC : 268 (50 seated + 218 standing)
- 3-car train set : 772
- 6-car train set : 1,576

3) Passenger capacity (@ 8 passengers per square meter of standee area)

Car width 3.2m in DPR

- DMC : 362 (42 seated + 320 standing )
- MC/TC : 381 (50 seated + 331 standing )
- 3-car train set : 1,105
- 6-car train set : 2,248

Car width 2.9m changed by PMRCL based on MOHUD guideline in July 2022

- DMC : 322 (42 seated + 280 standing)
- MC/TC : 341 (50 seated + 291 standing)
- 3-car train set : 985
- 6-car train set : 2,008

### 8.1.4 Future Prediction of Operation Plan

The PMRCL assumes the future operation plan as follows.

**Table 8-1: Future Operation Plan (Corridor 1)**

| Section | Year | Operation interval (min) | No. of rakes | | Total no. of cars | PHPDT |
|---|---|---|---|---|---|---|
| | | Peak | 3-car train | 6-car train | | |
| (Corridor 1) Danapur – Khemni Chak | 2024 | 4.3 | 11 (2) | 3 (0) | 51 | 14,516 |
| | 2031 | 3.5 | 7 (2) | 10 (2) | 81 | 23,127 |
| | 2041 | 3.3 | 7 (1) | 11 (2) | 87 | 25,323 |
| | 2051 | 3.0 | 3 (4) | 17 (0) | 111 | 32,011 |

( ) is number of reserved train

Source: DPR

**Table 8-2: Future Operation Plan (Corridor 2)**

| Section | Year | Operation interval (min) | No. of rakes | | Total no. of cars | PHPDT |
|---|---|---|---|---|---|---|
| | | Peak | 3-car train | 6-car train | | |
| (Corridor 2) Patna Junction – New ISBT | 2024 | 4.6 | 13 (2) | 0 | 39 | 11,252 |
| | 2031 | 3.5 | 17 (3) | 0 | 51 | 17,862 |
| | 2041 | 3.3 | 18 (3) | 0 | 54 | 19,507 |
| | 2051 | 3.0 | 20 (3) | 0 | 60 | 22,083 |

( ) is number of reserved train

Source: DPR

## 8.2 Reviews of Existing Studies and Proposals for Improvement

### 8.2.1 PHPDT by Demand projection

As results of Demand Projection, PHPDT is revised as follows. Each PHPDT values are reduced from DPR.

**Table 8-3: Revised PHPDT for Stations of Metro Corridor 1**

| Year | | 2028 | | 2031 | | 2041 | | 2051 | |
|---|---|---|---|---|---|---|---|---|---|
| Station | | To Khemni Chak | To Danapur | To Khemni Chak | To Danapur | To Khemni Chak | To Danapur | To Khemni Chak | To Danapur |
| Danapur | Saguna More | 1,933 | 1,541 | 2,188 | 1,784 | 3,224 | 2,618 | 5,016 | 3,975 |
| Saguna More | RPS More | 5,505 | 4,104 | 6,229 | 4,723 | 9,205 | 6,816 | 14,606 | 10,337 |
| RPS More | Patliputra | 7,385 | 5,569 | 8,333 | 6,402 | 12,265 | 9,242 | 19,412 | 14,073 |
| Patliputra | Rukanpura | 8,616 | 6,204 | 9,711 | 7,144 | 14,279 | 10,323 | 22,616 | 15,707 |
| Rukanpura | Raja Bazar | 10,811 | 8,394 | 12,567 | 9,463 | 17,481 | 13,778 | 26,875 | 21,653 |
| Raja Bazar | Patna Zoo | 11,794 | 9,506 | 13,856 | 10,616 | 18,912 | 15,764 | 28,620 | 25,071 |
| Patna Zoo | Vikas Bhawan | 11,116 | 9,845 | 14,298 | 10,985 | 19,358 | 16,419 | 29,111 | 26,182 |
| Vikas Bhawan | Vidyut Bhawan | 12,174 | 9,820 | 14,268 | 11,014 | 19,117 | 16,660 | 28,441 | 26,852 |
| Vidyut Bhawan | Patna Station | 11,034 | 9,880 | 12,974 | 11,033 | 17,017 | 17,010 | 25,111 | 27,625 |
| Patna Station | Mithapur | 9,303 | 9,287 | 10,491 | 11,056 | 14,603 | 15,842 | 22,406 | 25,325 |
| Mithapur | R. Nagar | 7,640 | 6,910 | 8,677 | 8,177 | 11,863 | 12,068 | 18,052 | 19,896 |
| R. Nagar | Jaganpura | 6,268 | 5,316 | 7,163 | 6,099 | 9,824 | 9,269 | 14,719 | 15,490 |
| Jaganpura | Khemni Chak | 5,913 | 4,827 | 6,775 | 5,527 | 9,239 | 8,446 | 13,755 | 14,243 |
| **MAX. PHPDT** | | **12,174** | | **14,298** | | **19,358** | | **29,111** | |

Source: JST

**Table 8-4: Revised PHPDT for Stations of Metro Corridor 2**

| Year | | 2028 | | 2031 | | 2041 | | 2051 | |
|---|---|---|---|---|---|---|---|---|---|
| Station | | To Zero Mile | To Patna Station | To Zero Mile | To Patna Station | To Zero Mile | To Patna Station | To Zero Mile | To Patna Station |
| Patna Station | Akashvani | 4,754 | 3,524 | 5,471 | 4,205 | 7,235 | 6,037 | 8,796 | 8,656 |
| Akashvani | Gandhi Maidan | 5,847 | 4,718 | 6,664 | 5,669 | 8,862 | 8,145 | 10,894 | 11,676 |
| Gandhi Maidan | PMCH | 6,873 | 5,635 | 7,705 | 6,641 | 10,285 | 9,507 | 12,759 | 13,460 |
| PMCH | University | 7,580 | 6,156 | 8,420 | 7,167 | 11,315 | 10,179 | 14,254 | 14,181 |
| University | Moin Stadium | 8,385 | 7,383 | 9,277 | 8,300 | 12,632 | 11,522 | 16,210 | 15,691 |
| Moin Stadium | Rajendra Nagar | 8,325 | 7,923 | 9,182 | 8,833 | 12,458 | 12,273 | 15,995 | 16,634 |
| Rajendra Nagar | Malahi Pakri | 7,825 | 8,423 | 8,458 | 9,557 | 11,518 | 13,213 | 14,839 | 17,790 |
| Malahi Pakri | Khemni Chak | 7,254 | 7,638 | 7,785 | 8,584 | 10,523 | 11,974 | 13,487 | 16,074 |
| Khemni Chak | Bhoot Nath | 6,784 | 6,561 | 7,252 | 7,225 | 9,563 | 10,215 | 11,989 | 13,787 |
| Bhoot Nath | Zero Mile | 6,165 | 5,752 | 6,640 | 6,155 | 8,723 | 8,652 | 10,788 | 11,596 |
| Zero Mile | New ISBT | 4,422 | 4,346 | 4,535 | 4,517 | 6,051 | 6,155 | 7,411 | 7,817 |
| **MAX. PHPDT** | | **8,423** | | **9,557** | | **13,213** | | **17,790** | |

Source: JST

### 8.2.2 Influence of Car Width Reduction

Car width is changed from 3.2n (in DPR) to 2.9m (in MOHUA guideline) by PMRCL in July 2022. The capacity of rolling stock is reduced by roughly 10% by the car width reduction. Confirmation about the influence of the car width reduction is as follows including improvement for train operation.

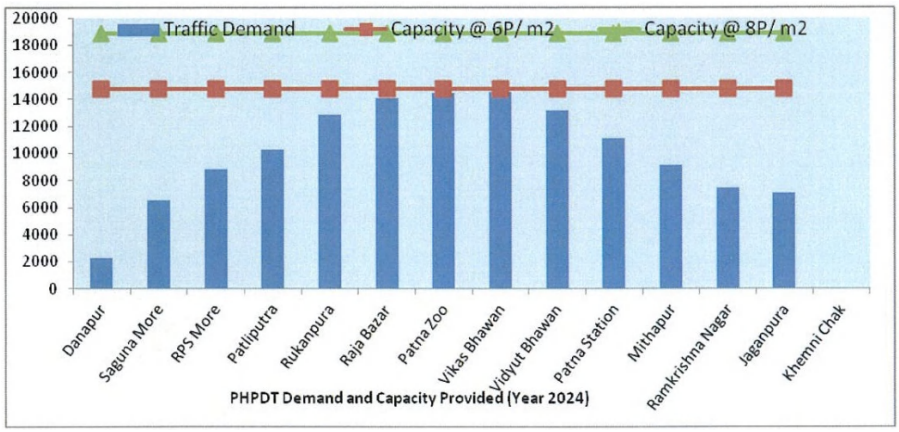
1) Change of Train Operation
   - Corridor 1 3 cars: 12, 6 cars: 3 (in DPR) ⟶ 3 cars: 10, 6 cars: 4
   - Corridor 2 3 cars : 12 (in DPR) ⟶ 3 cars: 11
   - Headway 4.3, 4.6 min. (in DPR) ⟶ 5.0 min.

2) Capacity of Corridor 1 at peak time (Ratio to crush load)
   - Number of trains / hour 3 cars: 10 × (60/70) = 8.6, 6 cars: 4 × (60/70) = 3.4
   - Ratio to crush load 12174 / (772 × 8.6 + 1576 × 3.4) = 1.02 = 102% based on Demand Projection
   - (Ratio to crush load 14516 / (772 × 8.6 + 1576 × 3.4) = 1.21 = 121% based on DPR)

3) Capacity of Corridor 2 at peak time (Ratio to crush load)
   - Number of trains / hour 3 cars : 11 × (60/55) = 12.0
   - Ratio to crush load 7707 / (772 × 12.0) = 0.83 = 83% based on Demand Projection
   - (Ratio to crush load 11252 / (772 × 12.0) = 1.21 = 121% based on DPR)

4) Reserved Train and Total number of cars
   - Reserved train 3 cars: 3 trains, 6 cars: 1 train
   - Total number of cars 3 × (10 + 11 + 3) + 6 × 5 = 102 cars (unchanged from DPR)

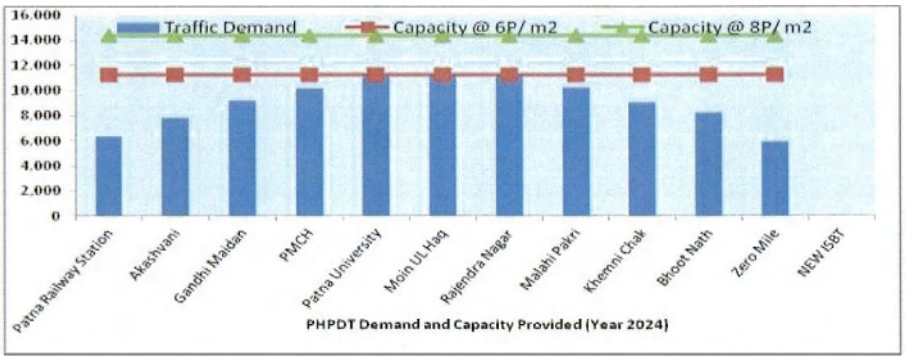
Ratio to crush load (@ 6 passenger/m²) at peak time on Corridor 1 is 102%, and Corridor 2 is 91%. Passenger demand of Patna Metro are shown in Figure 8-1 (Corridor 1) and Figure 8-2 (Corridor 2), the busiest sections are between limited number of stations. DPR in 2024 and Demand Projection in 2028 have the same tendency. Ratio to crush load 91 - 102% at peak time is acceptable.




Source: DPR

**Figure 8-1: Corridor 1 Passenger Demand in 2024 (Lines of Capacity are based on DPR values)**

It has the same tendency as Demand Projection in 2028.




Source: DPR

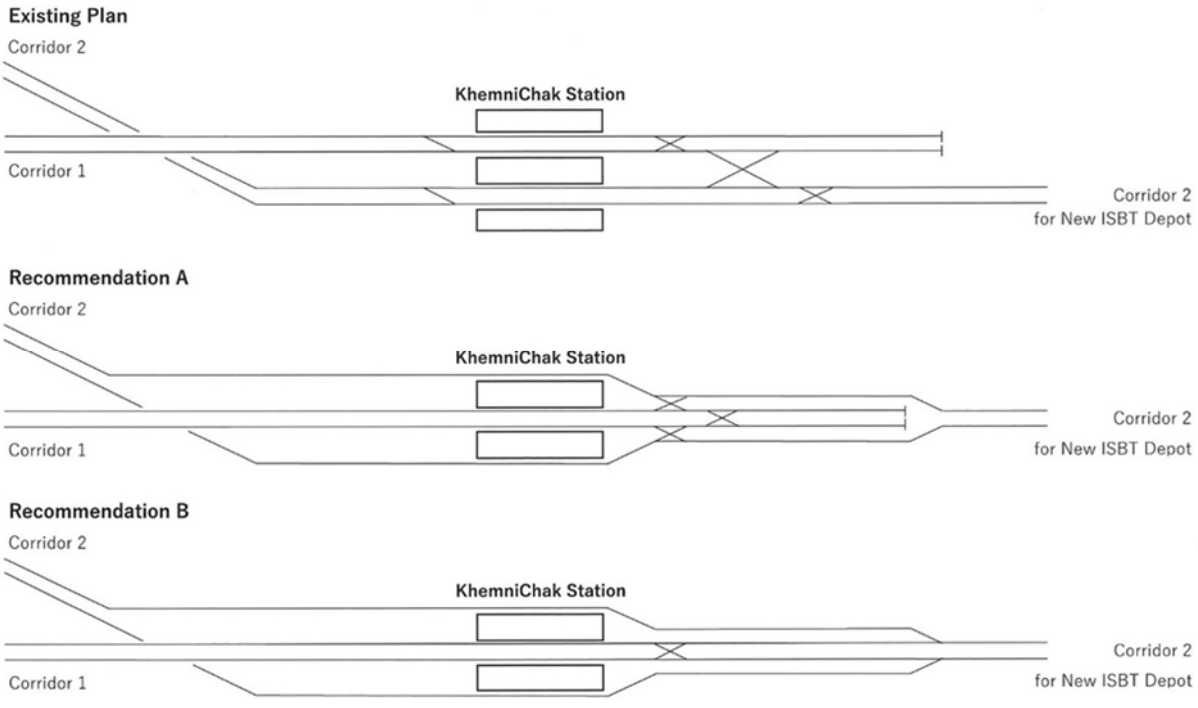
**Figure 8-2: Corridor 2 Passenger Demand in 2024 (Lines of Capacity are based on DPR values)**

It has the same tendency as Demand Projection in 2028.

### 8.2.3 In/Out Depot Trains on Corridor 2

Patna Metro has only one depot at the end of Corridor 2 New ISBT. Corridor 1 in/out depot trains must run on Corridor 2 (Khemni Chak – New ISBT) without passenger service, it is not only in the early morning and midnight but also before and after peak time. The junction station of both corridors Khemni Chak should have good alignment to prevent interference of each train.

The existing plan of alignment is shown in Figure 8-3, there are some routes across main line, and waiting time on main line or at platform will occur. JST recommendations to prevent interference and reduce waiting time which are shown in this figure. Recommendation A (model: Shirokane Takanawa station of Tokyo Metro) is possible to choose all route. Recommendation B (model: Mizonokuchi station of Tokyu Railway) is a solution with the minimum additional turnout.




Source: JST

**Figure 8-3: Existing Plan and Recommendation for Alignment of Khemni Chak**

However, construction of Khemni Chak station has already started, it is very difficult to change alignment including viaduct. Alternative recommendation is shown in Figure 13-5 and Figure 13-6, it is additional storage track outside depot to reduce number of in/out depot trains.

### 8.2.4 Concerns for "3 and 6 Cars" Mixed Operation

Train operation of Corridor 1 is "3 and 6 cars" mixed operation, there are some concerns as follows.

1) Mixed operation is existing (e.g. 4 and 6 cars, 6 and 8 cars in DMRC), but 3 and 6 cars train length is doubled and half different. The short train will be crowded and boarding/alighting time will be longer (passenger waiting at the end of the platform will rush for boarding), so there are possibility that on-time operation cannot be maintained.
2) As Table 8-1 and Table 8-2 at the beginning in 2024, there are no reserved train of 6 cars configuration. It means 6 cars train cannot be operated not only failed condition but also during monthly inspection of 6 cars train. It will cause confusion on a daily basis.
3) Initial cost of purchasing rolling stock will increase to prepare spare trains for 3 cars and 6 cars both.
4) Rescue operation must be considered for failed condition of one train on the maximum gradient. The ramp from underground to elevated is 40/1,000 gradient. 3 cars train cannot push 6 cars failed train on 40/1,000 gradient.

As described below 8.2.5 and 8.2.6, "3 and 6 cars" mixed train operation is possible. However, it is necessary to take measure to prevent problems. For example, passenger information at platform about number of vehicles of next train, balanced arrangement of "6 cars" train operation on Corridor 1, examination of tractive effort increasing at rescue operation, and so on.

### 8.2.5 Quantity of Rolling Stock

Train configuration for each corridor and each year is considered as follows without increasing total number of cars in DPR.

**Table 8-5: Number of Trains and Vehicles**

| | 2028 | | 2031 | | 2041 | | 2051 | |
|---|---|---|---|---|---|---|---|---|
| | 3 cars | 6 cars | 3 cars | 6 cars | 3 cars | 6 cars | 3 cars | 6 cars |
| Corridor 1 | 10 | 4 | 6 | 12 | 0 | 16 | 0 | 18 |
| Corridor 2 | 11 | 0 | 15 | 0 | 17 | 0 | 19 | 0 |
| Reserved | 3 | 1 | 3 | 2 | 3 | 2 | 3 | 3 |
| **Total trains** | **24** | **5** | **24** | **14** | **20** | **18** | **22** | **21** |
| **Total vehicles** | **102** | | **156** | | **168** | | **192** | |

Source: JST

- Total number of cars are same as DPR
- 4 sets of "3 cars" trains will be converted to 2 sets of "6 cars" trains in the future (around 2041). Rolling stock design should be included in preparation for the conversion of train configuration. In particular DMC front design (converted from evacuation door to gang way), unification of car length, and TCMS.

### 8.2.6 Rescue Operation on Maximum Gradient

Rescue scenario 6 cars dense crush load train failed on maximum gradient 4%
3 cars tare weight train push the failed train, is it possible?

1) Condition of calculation based on Table 11-2.
   - Tare weight 3 cars: 124.3 t, 6 cars: 245.2 t
   - Gross weight 3 cars: 174.5 t, 6 cars: 347.6 t
     at dense crush load = seated + standing 8 persons/sqm
   - Inertia mass DMC, MC: tare weight + 10%, TC: tare weight + 5%
   - Inertia mass + tare weight 3 cars: 134.7 t, 6 cars: 265.7 t
   - Inertia mass + gross weight 3 cars: 184.9 t, 6 cars: 368.1 t
   - Starting acceleration 1.2 m/s/s
   - Starting resistance 0.04 kN/t
   - Maximum gradient 4 %

2) Tractive effort of 3 cars at tare weight
   $134.7 \times 1.2 + 0.04 \times 124.5 = 166.6$ kN

3) Acceleration of rescue operation on 4% gradient
   $\{166.6 – (124.3 + 347.6) \times 0.04 \times 9.8\} / (134.7 + 368.1) < 0$ m/s/s - - - N/A
   It should be more than 0.1 m/s/s

4) Additional scenario 1 : Passengers get off the failed train
   - $\{166.6 – (124.3 + 245.2) \times 0.04 \times 9.8\} / (134.7 + 265.7) = 0.05$ m/s/s - - - N/A

5) Additional scenario 2 : Passengers get off the failed train + tractive effort increase 15%
   - $\{191.6 – (124.3 + 245.2) \times 0.04 \times 9.8\} / (134.7 + 265.7) = 0.11$ m/s/s - - - **OK**

   Adhesion: $191.6 / (42 \times 2 \times 9.8) = 0.23 = 23\%$ - - - **Acceptable**
   Sand to prevent slip should be prepared at gradient wayside for rainy condition.

### 8.2.7 Hourly Train Operation

Hourly Train Operation Plan for each corridor and each year is considered as follows.

## Table 8-6: Hourly Train Operation Plan: Corridor 1 (Danapur – Khemni Chak)

| Time of Day | 2028 | | | 2031 | | | 2041 | | 2051 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Headway in min. | 3 cars | 6cars | Headway in min. | 3 cars | 6 cars | Headway in min. | 6 cars | Headway in min. | 6 cars |
| 5 – 6 | 15 | 4 | | 15 | | 4 | 15 | 4 | 15 | 4 |
| 6 – 7 | 7.5 | 8 | | 6 | | 10 | 5.75 | 10.25 | 5 | 12 |
| 7 – 8 | 6 | 8.3 | 1.7 | 5 | 1.7 | 10.3 | 5 | 12 | 4.5 | 13.5 |
| **8 – 9** | **5** | **8.6** | **3.4** | **4** | **5** | **10** | **4.5** | **13.5** | **4** | **15** |
| **9 – 10** | **5** | **8.6** | **3.4** | **4** | **5** | **10** | **4.5** | **13.5** | **4** | **15** |
| 10 – 11 | 6 | 8.3 | 1.7 | 5 | 1.7 | 10.3 | 5 | 12 | 4.5 | 13.5 |
| 11 – 12 | 7.5 | 8 | | 6 | | 10 | 5.75 | 10.25 | 5 | 12 |
| 12 – 13 | 7.5 | 8 | | 6 | | 10 | 5.75 | 10.25 | 5 | 12 |
| 13 – 14 | 7.5 | 8 | | 6 | | 10 | 5.75 | 10.25 | 5 | 12 |
| 14 – 15 | 7.5 | 8 | | 6 | | 10 | 5.75 | 10.25 | 5 | 12 |
| 15 – 16 | 7.5 | 8 | | 6 | | 10 | 5.75 | 10.25 | 5 | 12 |
| 16 – 17 | 6 | 8.3 | 1.7 | 5 | 1.7 | 10.3 | 5 | 12 | 4.5 | 13.5 |
| **17 – 18** | **5** | **8.6** | **3.4** | **4** | **5** | **10** | **4.5** | **13.5** | **4** | **15** |
| **18 – 19** | **5** | **8.6** | **3.4** | **4** | **5** | **10** | **4.5** | **13.5** | **4** | **15** |
| 19 – 20 | 6 | 8.3 | 1.7 | 5 | 1.7 | 10.3 | 5 | 12 | 4.5 | 13.5 |
| 20 – 21 | 7.5 | 8 | | 6 | | 10 | 5.75 | 10.25 | 5 | 12 |
| 21 – 22 | 7.5 | 8 | | 6 | | 10 | 5.75 | 10.25 | 5 | 12 |
| 22 – 23 | 10 | 6 | | 7.5 | | 8 | 7.5 | 8 | 7.5 | 8 |
| 23 – 24 | 15 | 4 | | 15 | | 4 | 15 | 4 | 15 | 4 |
| Trains at peak | | 10 | 4 | | 6 | 12 | | 16 | | 18 |
| **Total no. of trains /direction/day** | | **145.6** | **20.4** | | **26.8** | **177.2** | | **200** | | **226** |
| | | | **166** | | | **204** | | | | |

Source: JST

**Table 8-7: Hourly Train Operation Plan: Corridor 2 (Patna Junction – New ISBT)**

| Time of Day | 2028 | | | 2031 | | | 2041 | | 2051 | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Headway in min. | 3 cars | | Headway in min. | 3 cars | | Headway in min. | 3 cars | Headway in min. | 3 cars |
| 5 – 6 | 15 | 4 | | 15 | 4 | | 15 | 4 | 15 | 4 |
| 6 – 7 | 7.5 | 8 | | 6 | 10 | | 6 | 10 | 5 | 12 |
| 7 – 8 | 6 | 10 | | 5 | 12 | | 4.5 | 13 | 3.75 | 16 |
| **8 – 9** | **5** | **12** | | **3.75** | **16** | | **3.25** | **18.5** | **3** | **20** |
| **9 – 10** | **5** | **12** | | **3.75** | **16** | | **3.25** | **18.5** | **3** | **20** |
| 10 – 11 | 6 | 10 | | 5 | 12 | | 4.5 | 13 | 3.75 | 16 |
| 11 – 12 | 7.5 | 8 | | 6 | 10 | | 6 | 10 | 5 | 12 |
| 12 – 13 | 7.5 | 8 | | 6 | 10 | | 6 | 10 | 5 | 12 |
| 13 – 14 | 7.5 | 8 | | 6 | 10 | | 6 | 10 | 5 | 12 |
| 14 – 15 | 7.5 | 8 | | 6 | 10 | | 6 | 10 | 5 | 12 |
| 15 – 16 | 7.5 | 8 | | 6 | 10 | | 6 | 10 | 5 | 12 |
| 16 – 17 | 6 | 10 | | 5 | 12 | | 4.5 | 13 | 3.75 | 16 |
| **17 – 18** | **5** | **12** | | **3.75** | **16** | | **3.25** | **18.5** | **3** | **20** |
| **18 – 19** | **5** | **12** | | **3.75** | **16** | | **3.25** | **18.5** | **3** | **20** |
| 19 – 20 | 6 | 10 | | 5 | 12 | | 4.5 | 13 | 3.75 | 16 |
| 20 – 21 | 7.5 | 8 | | 6 | 10 | | 6 | 10 | 5 | 12 |
| 21 – 22 | 7.5 | 8 | | 6 | 10 | | 6 | 10 | 5 | 12 |
| 22 – 23 | 10 | 6 | | 7.5 | 8 | | 7.5 | 8 | 7.5 | 8 |
| 23 – 24 | 15 | 4 | | 15 | 4 | | 15 | 4 | 15 | 4 |
| Trains at peak | | 11 | | | 15 | | | 17 | | 19 |
| **Total no. of trains /direction/day** | | **166** | | | **208** | | | **222** | | **256** |

Source: JST

### 8.2.8 Operation Distance of Trains and Cars

Vehicle kilometer for each corridor and each year is calculated as follows.

**Table 8-8: Vehicle Kilometer: Corridor 1 (Danapur – Khemni Chak)**

| | 2028 | | 2031 | | 2041 | | 2051 | |
|---|---|---|---|---|---|---|---|---|
| | 3 cars | 6 cars | 3 cars | 6 cars | | 6 cars | | 6 cars |
| Length km | 17.1 | 17.1 | 17.1 | 17.1 | | 17.1 | | 17.1 |
| No. of working days per year | 340 | 340 | 340 | 340 | | 340 | | 340 |
| No. of trains per day each way | 145.6 | 20.4 | 26.8 | 177.2 | | 200 | | 226 |
| Daily train km | 4980 | 698 | 917 | 6060 | | 6840 | | 7729 |
| Annual train km ($10^5$ km) | 16.93 | 2.37 | 3.12 | 20.60 | | 23.26 | | 26.28 |
| Annual vehicle km ($10^5$ km) | 50.80 | 14.24 | 9.35 | 123.62 | | 139.54 | | 157.67 |
| | 65.04 | | 132.97 | | 139.94 | | 157.67 | |

Source: JST

**Table 8-9: Vehicle Kilometer: Corridor 2 (Patna Junction – New ISBT)**

| | 2028 | | 2031 | | 2041 | | 2051 | |
|---|---|---|---|---|---|---|---|---|
| | 3 cars | | 3 cars | | 3 cars | | 3 cars | |
| Length km | 13.6 | | 13.6 | | 13.6 | | 13.6 | |
| No. of working days per year | 340 | | 340 | | 340 | | 340 | |
| No. of trains per day each way | 166 | | 208 | | 222 | | 256 | |
| Daily train km | 4515 | | 5658 | | 6038 | | 6963 | |
| Annual train km ($10^5$ km) | 15.35 | | 19.24 | | 20.53 | | 23.67 | |
| Annual vehicle km ($10^5$ km) | 46.05 | | 57.71 | | 61.59 | | 71.02 | |
| | | 46.05 | | 57.71 | | 61.59 | | 71.02 |

Source: JST

# 9. Signaling and Telecommunication

## 9.1 Overview of Existing Studies

### 9.1.1 Signaling Facilities

#### (1) Train Control System

PMRCL plans to introduce CBTC (Communication Based Train Control system), the train control system utilizing radio communication. CBTC conforms to IEEE 1474.1, IEEE 1474.2, IEEE 1474.3, IEC 62267, IEC 62278, IEC 62425, IEC 62290-1, IEC 62290-2, and IEC 62290-3, International standards. CBTC also conforms to the Indian regulation for licensing and radiation of frequency bands as per DoT, TRAI, and WPC guidelines. (However, CBTC will use the ISM band (2.4GHz) and won't require the license.)

The main technical specifications of CBTC for PMRCL are shown in the below table.

**Table 9-1: The main technical specifications of CBTC**

| Main System/Device/ Equipment | The Main technical specifications |
|---|---|
| Automatic Train Supervision (ATS) subsystem | ATS subsystem enables monitoring and control of trains at OCC/BCC/DCC/SCRs.<br>The main technical specifications of ATS subsystem are planned as follows:<br>• Train describer, monitoring, and continuous regulation of train movement<br>• Automatic and manual route setting<br>• Automatic and manual train regulation<br>• Short loop management<br>• Timetable management<br>• Display and plotting of train journey graph<br>• Information transmission for display on PIDS and announcement on PA system<br>• Monitoring and control for CBTC Equipment (ATS, ATP, ATO, and CBI device)<br>• Operation assistance (alarm output and system-operating data storage, etc.)<br>• The development process of ATS conforms to SIL 2 level of CENELEC standards EN 50126, EN 50128, and EN 50129. |
| Automatic Train Protection (ATP) subsystem | ATP subsystem is the primary subsystem in CBTC and enables its safety with the fail-safe principle.<br>The main technical specifications of ATP subsystem are planned as follows:<br>• Primary train detection method for CBTC-equipped train<br>• Train location detection by onboard device, train location information transmission through radio communication (from onboard devices to ground facilities)<br>• Signals and line information transmission through radio communication (from ground facilities to onboard devices)<br>• The track-related speed profile (ATP speed profile) generation by continuous computation from the line data and the train data<br>• Safety train separation (ATP gives the movement authority based on the moving block principle.)<br>• Speed restriction section monitoring<br>• Monitoring of maximum permitted speed on the line<br>• Maximum permissible train speed monitoring<br>• Constant speed monitoring<br>• Monitoring of maximum speed set by the onboard unit<br>• Monitoring of braking curve for defined target point (stopping point or speed restriction section, etc.)<br>• Monitoring of stopping point to ensure that the train doesn't run into the hazard point located beyond |

| Main System/Device/ Equipment | The Main technical specifications |
|---|---|
| | • Monitoring for stopping the train in the target area of the station (ATP monitors the train to stop within the stopping window. The train is the application of FSB (Full Service Brake) or EB (Emergency Break) in case of breach of ATP speed profile.)<br>• Cab signaling<br>• The onboard device is redundant. Therefore, the changeover in the event of failure of one unit is automatic without the train operator's intervention.<br>• ATP conforms to SIL 4 level of CENELEC standards EN 50126, EN 50128, and EN 50129. |
| Automatic Train Operation (ATO) subsystem | ATO subsystem enables automatic train operation between stations under ATP subsystem, which ensures safety.<br>The main technical specifications of ATO subsystem are planned as follows:<br>• Door automatic opening (after the train station stops at the station)<br>• Automatic train operation (by closing doors and pressing the start button after the train is ready to start)<br>• Train operation management according to headway or timetable<br>• Station dwell time control<br>• Automatic turn-back process control at the terminal station (automatic reversal control, etc.)<br>• The development process of ATO conforms to SIL 2 level of CENELEC standards EN 50126, EN 50128, and EN 50129. |

Source: DPR, JST

### (2) Computer-Based Interlocking Device and Other Signaling Facilities

The main technical specifications of Computer-Based Interlocking Device and Other Signaling Facilities for PMRCL are shown in the below table.

**Table 9-2: The main technical specifications of CBI and Other Signaling Facilities**

| Main System/Device/ Equipment | The Main technical specifications |
|---|---|
| Computer-Based Interlocking (CBI) Device | The main technical specifications of CBI Device are planned as follows:<br>• Train describer, monitoring, and continuous regulation of train movement at SCRs<br>• Automatic and manual route setting at SCRs<br>• Automatic and manual train regulation at SCRs<br>• Line Side Signal control at SCRs<br>• Electric point machine control at SCRs<br>• Hot standby system<br>• Built-in Block function<br>• CBI conforms to SIL 4 level of CENELEC standards EN 50126, EN 50128, and EN 50129.<br>• CBI also conforms to RDSO/SPN/192/2005, the Indian standard. |
| Train Detection Device (Digital Axel Counter) | The main technical specifications of Digital Axel Counter are planned as follows:<br>• Secondary train detection method for CBTC-equipped train (Backup device in case of ATP failure)<br>• Train detection method for nonCBTC-equipped train<br>• In equivalent area to CBTC controllable area<br>• The device consists of the wheel sensor, the indoor unit, the junction box in the field, and cables between the wheel sensor and the indoor unit. |
| Line Side Signal | The main technical specifications of Line Side Signal are planned as follows:<br>• Secondary train operation method for CBTC-equipped train (Backup device in case of ATP failure)<br>• Train operation method for nonCBTC-equipped train<br>• At stations with CBIs for point protection (for bidirectional operation)<br>• Also, at intermediate locations between New ISBT Depot exit and New ISBT station entry (for induction of trains to optimize headway)<br>• LED type signal for high reliability and less maintenance effort |

| Main System/Device/ Equipment | The Main technical specifications |
|---|---|
| | • Line Side Signal conforms to RDSO/SPN/153/2011, the Indian standard. |
| Electric Point Machine | The main technical specifications of Electric Point Machine are planned as follows:<br>• Non-trainable, high thrust, additional external mechanical locking and 3 phase (380-415 V AC) electric type conforming any international standard for mainline.<br>• Non-trainable, clamp type locking, additional external mechanical locking and 110V DC electric type conforming IRS standard for New ISBT Depot. |
| Close Circuit Television (CCTV) System<br>• Onboard CCTV ~ OCC(BCC), etc. | The main technical specifications of CCTV System (Onboard CCTV ~ OCC, etc.) are planned as follows:<br>• Information transmission between the train and OCC/BCC/DCC/SCRs through CCTV Network (including radio network)<br>• 5.8GHz (ISM band) for CCTV radio network (different from 2.4GHz for CBTC radio network)<br>• CCTV network separate from CBTC network (considering the critical/vital nature of CBTC network)<br>• CCTV MMIs at OCC/BCC/DCC/SCRs<br>• Playback of selected camera recordings<br>• Playback of recorded/logged events<br>• Display on the CCTV MMIs and Large Video Screens |

Source: DPR, JST

### (3) Others

- OCC (Operation Control Centre) is planned at New ISBT Depot, and BCC (Backup Control Center) is planned at Patna Junction Station.
- CBI for Corridor 1 is planned at Danapur, Patna Zoo, and Khemni Chak stations. The CBI at Khemni Chak Station is planned to be used commonly with Corridor 2.
- CBI for Corridor 2 is planned at Patna Junction, Malahi Pakri, and New ISBT stations.
- The independent CBI is planned at New ISBT Depot.
- Vehicles of Corridor 1 are planned to run on some sections of Corridor 2 (between Khemni Chak Station (The terminal station of Corridor 1) and New ISBT Depot) to accommodate them at New ISBT Depot.
- The Mainline is planned to be secured by ATP. In addition, some track sections in New ISBT Depot (IBL shed, Workshop shed, PWL, ICS, ETU and RGM, Loading/Unloading track, Track machine, mobile welding plant siding, etc.) are planned to be manually secured. Other track sections in New ISBT Depot are planned to be secured by ATP.
- Shunting routes and Electric Points in New ISBT Depot are planned to be set by the workstation in the New ISBT Depot control room.
- Corridor 1 and 2 are planned to introduce CBTCs manufactured by the same supplier because vehicles of Corridor 1 are planned to run on some sections of Corridor 2 and CBTCs manufactured by different suppliers are not compatible.
- The uninterrupted power supply (UPS) is planned to be commonly used for Train Control System (CBTC), Signaling Facilities, Telecommunication Facilities, and AFC system and supply power backup for about 2 hours.
- All equipment rooms are planned to be air-conditioned.

### 9.1.2 Telecommunication Facilities

#### (1) Telecommunication Facilities

The main technical specifications of the main Telecommunication Facilities for PMRCL are shown in the below table.

**Table 9-3: The Main Technical Specifications of Telecommunication Facilities**

| Main System/Device/ Equipment | The Main technical specifications |
|---|---|
| Transmission System | The main technical specifications of the Transmission System are planned as follows:<br>• FOTS (Fiber Optics Transmission System) and IP-MPLS (IP-Multi-Protocol Label Switching) proven in Indian railway<br>• Outdoor single-mode optical fiber cable (144 cores or more: backbone optical fiber cable)<br>• Steel armored, fire-retardant, fire-resistance, low-smoke, and zero-halogen optical fiber cable<br>• Two backbone optical fiber cables in loop configuration (redundancy configuration)<br>• Optical fiber cable conforms to the latest TEC and RDSO specifications, the Indian standard.<br>• High-capacity and redundant core routers (GEIP (Gigabit Ethernet IP)- MPLS) at four important locations (Core network consists of these routers interconnected in the near-full mesh configuration over 100GE interfaces.)<br>• Redundant routers (GEIP (Gigabit Ethernet IP)- MPLS) at OCC/BCC/New ISBT Depot/all stations/any other location (Distribution network consists of these routers.)<br>• Redundant layer-3 aggregation and layer-2/layer-3 switches or routers at New ISBT Depot/all stations/any other location (Access network consists of these switches and routers for all IP end devices and interfaces with all subsystems.)<br>• The transmission System conforms to ITU-T, IEEE, IETF, and RFC, International standards, or internationally accepted requirements. |
| Telephone Exchange (PBX) | The main technical specifications of PBX (SIP (Session Initiation Protocol) Server) are planned as follows:<br>• About 3,000 users and 750 concurrent calls (expandable up to 10,000 users, 1,500 concurrent calls) (SIP-PBX at OCC/BCC)<br>• 500 subscribers and 250 concurrent calls (SIP PBX at New ISBT Depot)<br>• 120 subscribers and 60 concurrent calls (SIP PBX at underground stations)<br>• 60 subscribers and 30 concurrent calls (SIP PBX at elevated stations) |
| Mobile Radio Communication System (TETRA) | The main technical specifications of TETRA are planned as follows:<br>• Land mobile radio open standard for digital trunked radio technology (Digital type, duplex operation)<br>• Minimum 8 channels<br>• 380-400MHz<br>• Fixed radio set at OCC/BCC/stations. Handheld set for maintainers and security personnel<br>• Information transmission through radio communication between trains, OCC/BCC/stations, and handheld sets<br>• Radio base station equipment with redundant configuration<br>• TETRA conforms to ITU-T, ITU-R, UIC recommendation, and ETSI.<br>• TETRA also conforms to the Indian regulation for licensing and radiation of frequency bands as per DoT, TRAI, and WPC guidelines. |
| Public Address (PA) System | The main technical specifications of PA System are planned as follows:<br>• Automatic announcements of the destination of the subsequent trains linked to ATS<br>• Automatic announcements for safety and security<br>• Extensive system suitable for emergency evacuation<br>• Fire-resistance, low-smoke, and zero-halogen cables<br>• PA System conforms to IEC 60628 or any equivalent International/Indian standard and EN54xxx or any equivalent International/Indian standard |

| Main System/Device/ Equipment | The Main technical specifications |
|---|---|
| Centralized Clock System (GNSS synchronization) | The main technical specifications of Centralized Clock System are planned as follows:<br>• Master clock synchronized with the GNSS signal<br>• Slave clocks synchronized with the master clock time<br>• Onboard devices and all subsystems (including Signaling Facilities) are synchronized with master clock time (through IP and radio networks) |
| Passenger Information Display System (PIDS) | The main technical specifications of PIDS are planned as follows:<br>• True color LED type (at station platforms)<br>• LED-backlit LCD type (at station concourses)<br>• Flat-panel with LCD or LED as electronic Passenger Information Display Board<br>• Display linked to ATS and by manual input from OCC/station<br>• Visual display of train running status<br>• Information display including destination, platform numbers, arrival/departure time, emergency messages, etc. in Hindi and English<br>• IEC as applicable or any equivalent International/Indian standard |
| Close Circuit Television (CCTV) System | The main technical specifications of CCTV System are planned as follows:<br>• CCTV cameras for all public and selected areas such as tunnel cross passages, ancillary buildings, OCC/BCC/SCRs<br>• Full coverage and High-quality surveillance for crowded control and other emergencies<br>• IP based system<br>• Recording and storage facilities (to record and store events for seven days minimum)<br>• IEC 60268 as applicable or any equivalent International (ONVIF, CE/FCC/UL, etc.)/Indian standard |
| Central Voice Recording System (CVRS) & Digital Voice Recording System (DVRS) | The main technical specifications of CVRS are planned as follows:<br>• Radio communication recording<br>• Live/Emergency broadcast ( from OCC/BCC and all Direct Line Consoles) recording<br>• Live announcement (from OCC/BCC to stations) recording<br>• Emergency telephone communication (at OCC/BCC/underground sections) recording<br>• Free space microphone ( at OCC/BCC) recording<br>The main technical specifications of DVRS are planned as follows:<br>• Conversation recording ( between all telephones, including Direct Line Consoles, Help Point Phones, and Emergency Telephone Lines) |
| Central Fault Reporting System (CFRS) | The main technical specifications of CFRS are planned as follows:<br>• Integrated system for monitoring and controlling Telecommunication Facilities and for storing maintenance data of Telecommunication Facilities (for alarm management and failure analysis)<br>• Information transmission between individual NMS (Network Management Systems) and CFRS (alarm notification, maintenance data, etc.)<br>• Monitored systems<br>▪ PA System<br>▪ PIDS<br>▪ Centralized Clock System<br>▪ Telephone Exchange (PBX)<br>▪ Mobile Radio Communication System (TETRA)<br>▪ CCTV System<br>▪ Transmission System |

Source: DPR, JST

### (2) Others

- The uninterrupted power supply (UPS) is planned to be commonly used for Train Control System (CBTC), Signaling Facilities, Telecommunication Facilities, and AFC system and supply power backup for about 2 hours.
- All equipment rooms are planned to be air-conditioned.

## 9.2 Reviews of Existing Studies and Proposals for Improvement

### 9.2.1 Signaling Facilities

#### (1) Conformity Review with International Standards/Regional Standards and Appropriateness Review of Facility Plan

JST reviewed whether PMRCL's signaling facilities have adopted appropriate International/Regional Standards. The International/Regional Standards adopted for PMRCL's signaling facilities are shown in the following table

**Table 9-4: International/Regional Standards adopted for PMRCL's signaling facilities**

| The main International/Regional Standards | | | | | Remark |
|---|---|---|---|---|---|
| | | International Standards | Regional Standards | | |
| | | | Overseas | Domestic | |
| ➢ Train Control System (CBTC)<br>• Automatic Train Supervision (ATS, SIL 2)<br>• Automatic Train Protection (ATP, SIL 4)<br>• Automatic Train Operation (ATO, SIL 2)<br>➢ Computer-Based Interlocking Device (CBI, SIL 4) | IEC 62278 | ✓ | | | RAMS • SIL (Equivalent to EN 50126) |
| | IEC 62425 | ✓ | | | RAMS • SIL (Equivalent to EN 50129) |
| | EN 50126 | | ✓ | | RAMS • SIL |
| | EN 50128 | | ✓ | | RAMS • SIL |
| | EN 50129 | | ✓ | | RAMS • SIL |
| ➢ Train Control System (CBTC)<br>• Automatic Train Supervision (ATS)<br>• Automatic Train Protection (ATP)<br>• Automatic Train Operation (ATO) | IEEE 1474.1 | ✓ | | | CBTC |
| | IEEE 1474.2 | ✓ | | | CBTC |
| | IEEE 1474.3 | ✓ | | | CBTC |
| | IEC 62267 | ✓ | | | ATO, etc. |
| | IEC 62290-1 | ✓ | | | transport management and command/control systems |
| | IEC 62290-2 | ✓ | | | |
| | IEC 62290-3 | ✓ | | | |
| | Guidelines<br>• DoT<br>• TRAI<br>• WPC | | | ✓ | CBTC(Radio)+<br>+ CBTC doesn't require a license to use the ISM band (2.4GHz). |
| ➢ Computer-Based Interlocking Device (CBI) | RDSO/SPN/192/2005 | | | ✓ | |
| ➢ Line Side Signal (LED Type) | RDSO/SPN/153/2011 | | | ✓ | |
| ➢ Electric point machine | IRS: S24 | | | ✓ | New ISBT Depot only |

Source: JST

### 1) Conformity with International Standards/Regional Standards

**<Possibility of being restricted by International/Regional Standards>**

JST has confirmed that PMRCL's signalling facilities would have few constraints imposed by International Standards or by Regional Standards established by Regional Authorities, the Indian Ministry of Railways, related Authorities, etc., for the following reasons.

- PMRCL's signaling facilities are equivalent to or similar to those proven in India.
- PMRCL's signaling facilities are planned considering International Standards or Regional Standards established by Regional Authorities, the Indian Ministry of Railways, related Authorities, etc.

JST has also confirmed that PMRCL has recognized that PMRCL's signaling facilities aren't restricted to International/Regional Standards.

**<Conformity with Regional Standards for the safety certification (SIL)>**

PMRCL plans to conform to CENELEC Standards for the safety certification (SIL) of its signaling facilities, such as CBTC. CENELEC Standards are European Regional Standards. JST guessed it would be difficult for some suppliers to bid on the project if PMRCL plans to conform only to CENELEC Standards. JST evaluates the construction cost issue is essential for PMRCL, and the construction cost could be lower if PMRCL could increase the number of bidders. Therefore, JST suggested that PMRCL would better change the plan to conform to International Standards such as ISO and IEC for its signaling facilities' safety certification (SIL).

JST inquired why PMRCL plans to conform only to the CENELEC Standard for its signaling facilities' safety certification (SIL) and received the following responses.

- PMRCL's specifications provide the safety certification (SIL-4/SIL-2) of CENELEC Standards or other recognized International Standards equivalent to CENELEC. However, if other recognized International Standards are followed in place of CENELEC, the following conditions are required to be met:
  - A copy of the Standards followed shall be submitted in English language.
  - A certificate from an independent recognized body shall be submitted stating that the proposed Standards are equivalent to CENELEC Standards.
  - Credentials of the independent recognized body issuing such certificates shall be submitted for verification by the Engineer.
  - The certificate of validator certifying that the system is equivalent to CENELEC SIL-4/SIL-2 compliant shall also be submitted.

That means PMRCL can also accept other recognized International Standards, such as ISO and IEC. Some Indian metro projects adopted the above process to conform to other recognized International Standards such as ISO and IEC.

JST has confirmed that PMRCL's signaling facilities have adopted appropriate International/Regional Standards.

JST recommends that PMRCL works on the project after confirming the conformity with International/Regional Standards if PMRCL changes The Signaling Facility Plan at the detailed design phase.

2) Appropriateness of Facility Plan

**<CBTC>**

PMRCL plans to run vehicles of Corridor 1 on some sections of Corridor 2 (between Khemni Chak Station (The terminal station of Corridor 1) and New ISBT Depot) to accommodate them at New ISBT Depot. JST confirmed it is challenging to introduce CBTCs manufactured by different suppliers for Corridor 1 and 2, considering that vehicles of Corridor 1 will be run on some sections of Corridor 2 and that CBTCs manufactured by different suppliers are not compatible.

JST inquired about The PMRCL's Signaling Facility Plan for CBTC and received the following response.

- PMRCL plans to introduce CBTCs manufactured by the same supplier for Corridor 1 and 2.

**<The other facilities>**

JST has confirmed The PMRCL's signaling facilities other than CBTC are also equivalent to or similar to those proven in India.

JST has confirmed The PMRCL's Signaling Facility Plan is appropriate.

## (2) Appropriateness Review of Facility Plan suitable for the transportation capability based on traffic demand forecasts

**<CBTC>**

PMRCL plans to introduce CBTC, which can operate trains at minimum 2 minutes headway. In addition to CBTC as the train control system, PMRCL had also considered the feasibility of introducing DTG (Distance To Go), which is introduced on DMRC Phase 1 and 2 lines, etc. DTG is the train control system that works on the fixed block principle using AF track circuits (the train detection device).

According to PMRCL, the minimum headway of DTG is 2 minutes 30 seconds. PMRCL targets introducing its transportation system to achieve future transportation capability of up to 67,000 PHPDT.

In this case, PMRCL needs to operate trains at a minimum of 2 minutes headway.

JST has confirmed it is appropriate for PMRCL to introduce CBTC.

JST has confirmed The PMRCL's Signaling Facility Plan is suitable and appropriate for the transportation capability based on traffic demand forecasts.

### (3) Procurement Feasibility Review from India and other countries (including Japan), Procurement Feasibility Review over the medium-to-long term

#### 1) Procurement Feasibility from India and other countries

**<Conformity with Regional Standards for the safety certification (SIL)>**

PMRCL plans to conform to CENELEC Standards for the safety certification (SIL) of its signaling facilities, such as CBTC. CENELEC Standards are European Regional Standards. JST guessed it would be difficult for some suppliers to bid on the project if PMRCL plans to conform only to CENELEC Standards. JST evaluates the construction cost issue is essential for PMRCL, and the construction cost could be lower if PMRCL could expand its methods of Procurement. Therefore, JST suggested that PMRCL would better change the plan to conform to International Standards such as ISO and IEC for its signaling facilities' safety certification (SIL).

JST inquired why PMRCL plans to conform only to the CENELEC Standard for its signaling facilities' safety certification (SIL) and received the following response.

- PMRCL's specifications provide the safety certification (SIL-4/SIL-2) of CENELEC Standards or other recognized International Standards equivalent to CENELEC. However, if other recognized International Standards are followed in place of CENELEC, the required documents and certificates must be submitted and approved by PMRCL.
  That means PMRCL can also accept other recognized International Standards, such as ISO and IEC.

JST has confirmed that PMRCL has considered Procurement Feasibility from around the world for its signaling facilities.

#### 2) Procurement Feasibility over the medium-to-long term

**<Various Facilities>**

PMRCL plans to conform to International Standards such as IEEE, IEC, etc., Standards equivalent to International Standards, and Regional Standards such as IRS and RDSO of domestic Standards. PMRCL also plans to introduce signaling facilities that are proven or available worldwide or in India.

JST has confirmed that PMRCL has considered Procurement Feasibility over the medium-to-long term for its signaling facilities.

### (4) Appropriateness Review of Facility Flexibility and Stability

#### 1) Facilities Flexibility

**<CBTC>**

Many global and Indian metro projects have introduced CBTC, which can achieve the moving block principle and potentially achieve DTO/UTO. The onboard device calculates the train position continuously, and CBTC recognizes its position through CBTC radio. Therefore, CBTC can stably detect the train position without track circuits. CBTC uses software to achieve the moving block principle.

Therefore, JST expects CBTC is appropriate for future transportation improvements because CBTC would allow future transportation capability enhancement without software modification or with reasonable software modification.

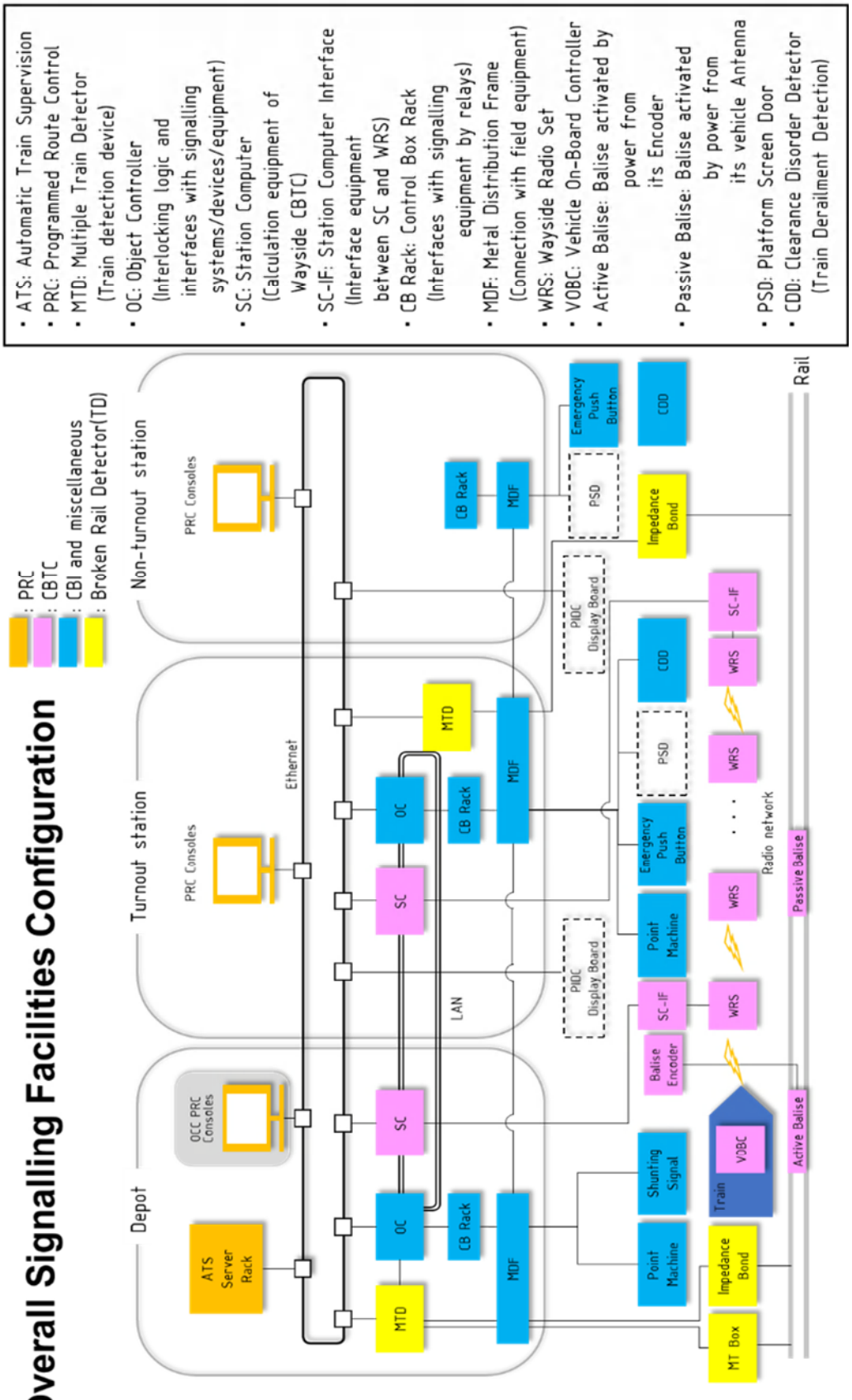
JST has confirmed that PMRCL has considered Facilities Flexibility for its signaling facilities.

### 2) Facilities Stability

**<Various Facilities>**

PMRCL plans various measures for data security and electrical interference protection, introduction of different networks for CCTV and CBTC to ensure data security for CBTC, and introduction of power and signaling cables separately to protect against electrical interference.

JST has confirmed that PMRCL has considered Facilities Stability for its signaling facilities.




Source: Nippon Signal Co., Ltd. , JST (Add comment)

**Figure 9-1: Example of Overall signaling Facilities Configuration**

### (5) Proposals for Improvement

PMRCL plans to introduce the latest systems/devices/equipment available and standardized worldwide.

If PMRCL changes its plan to introduce an additional system/device/equipment or specification at the detailed design phase, an additional interface (including hardware or software) could be needed to connect with the existing system/device/equipment. In addition, the additional construction cost and procurement/ construction period could be needed because systems/devices/equipment could be more complex.

JST recommends that PMRCL introduces the systems/devices/equipment or specification within the scope of the current plan.

- Regarding this JST proposal, JST has received the comment from PMRCL that the majority of the systems/devices/equipment or specification shall be within the scope of the current plan at the detailed design phase.

Corridors 1 and 2 around Khemni Chak Station are elevated sections proximate to each other.

PMRCL needs to provide documents to RDSO certifying interference robustness for CBTC Radio system in both out-of-band and in-band interferences.

JST recommends that PMRCL ensures the CBTC radio bands for Corridor 1 and 2 don't interfere at the detailed design stage.

- Regarding this JST proposal, JST has received the comment from PMRCL that at the detailed design stage, it shall be ensured that the CBTC radio bands for Corridor 1 and 2 don't interfere in the proximity of Corridor 1 and 2 around Khemni Chak Station.

PMRCL plans to use UPSs commonly for its signaling facilities (including the train control system), telecommunication facilities, and AFC system facilities.

JST recommends PMRCL to use UPSs for facilities that could directly affect the train operation and UPSs for facilities that could not directly affect the train operation separately, with the perspective of stable train operation.

- Regarding this JST proposal, JST has received the following comments from PMRCL.
  - As per standard practice of DMRC from Phase 1/2/3 including Phase 4 projects, the UPS of S&T is designed and commissioned common for Signaling, Telecommunication, and AFC facilities keeping appropriate safety checks while designing to avoid failure of entire UPS due to fault in any other subsystems such as Telecommunication/AFC.
  - Hence, for the Patna Metro Rail Construction Project also, a common UPS system with physically separate feeding MCCBs of appropriate ratings at the output ACDB panel of the UPS system has been planned for Signaling, AFC, Telecommunication, and other critical services which are essential for train operation.
  - Also, using common UPS for Signaling facilities along with Signaling, AFC, Telecommunication, and other critical services which are essential for train operation, cost of the contract in terms of Supply, installation, and commissioning, and then in terms of regular maintenance cost shall be reduced.

- JST agrees with the PMRCL's UPS installation method, as the planned method will likely lead to acceptable and stable train operations and cost savings.

### 9.2.2 Telecommunication Facilities

#### (1) Conformity Review with International Standards/Regional Standards and Appropriateness Review of Facility Plan

**Table 9-5: International/Regional Standards adopted for Telecommunication facilities**

| The main International/Regional Standards | | | | | Remark |
|---|---|---|---|---|---|
| | | International Standards+ | Regional Standards | | |
| | | | Overseas | Domestic | |
| ➢ Transmission System | ITU-T Related Standards | ✓ | | | |
| | IEEE Related Standards | ✓ | | | |
| | IETF Related Standards | ✓ | | | |
| | RFC Related Standards | ✓ | | | |
| ➢ Mobile Radio Communication System (TETRA) | ITU-T Related Standards | ✓ | | | |
| | ITU-R Related Standards | ✓ | | | |
| | UIC recommendation | ✓ | | | |
| | ETSI | | ✓ | | |
| | Guidelines<br>• DoT<br>• TRAI<br>• WPC | | | ✓ | |

+ "International Standards" in the table also include standards established by international parties and companies.

Source: JST

1) Conformity with International Standard/Regional Standards

**<Possibility of being restricted by International/Regional Standards>**

JST has confirmed that PMRCL's telecommunication facilities would have few constraints imposed by International Standards or by Regional Standards established by Regional Authorities, the Indian Ministry of Railways, related Authorities, etc., for the following reasons.

- PMRCL's telecommunication facilities are equivalent to or similar to those proven in India.
- PMRCL's telecommunication facilities are planned considering International Standards or Regional Standards established by Regional Authorities, the Indian Ministry of Railways, related Authorities, etc.

JST has also confirmed that PMRCL has recognized that PMRCL's telecommunication facilities aren't restricted to International/Regional Standards.

JST recommends that PMRCL work on the project after confirming the conformity with International/Regional Standards if PMRCL changes The Telecommunication Facility Plan at the detailed design phase.

**<Conformity with Regional Standards>**

PMRCL plans to conform to CENELEC Standards for some telecommunication facilities. CENELEC Standards are European Regional Standards. JST guessed it would be difficult for some suppliers to bid on the project if PMRCL plans to conform to CENELEC Standards.

JST evaluates the construction cost issue is essential for PMRCL, and the construction cost could be lower if PMRCL could increase the number of bidders.

JST inquired why PMRCL plans to conform to the CENELEC Standard for some telecommunication facilities and received the following response.

- PMRCL's specifications provide CENELEC Standards or other recognized International Standards equivalent to CENELEC. However, if other recognized International Standards are followed in place of CENELEC, the following conditions are required to be met:
  - A copy of the Standards followed shall be submitted in the English language.
  - A certificate from an independent recognized body shall be submitted stating that the proposed Standards are equivalent to CENELEC Standards.
  - Credentials of the independent recognized body issuing such certificates shall be submitted for verification by the Engineer.

JST has confirmed that PMRCL's telecommunication facilities have adopted appropriate International/Regional Standards.

JST recommends that PMRCL works on the project after confirming the conformity with International/Regional Standards if PMRCL changes The Telecommunication Facility Plan at the detailed design phase.

2) Appropriateness of Facility Plan

**<Various Facilities>**

JST has confirmed that The PMRCL's telecommunication facilities are equivalent to or similar to those proven in India and the PMRCL's Telecommunication Facility Plan is appropriate.

### (2) Appropriateness Review of Facility Plan suitable for the transportation capability based on traffic demand forecasts

**<Various Facilities>**

PMRCL plans to configure the backbone fiber optic cables for the Transmission System in consideration of its extension to the next-generation transportation network. PMRCL also plans to introduce Telephone Exchanges (SIP PBX) for OCC/BCC for 10,000 users and other facilities to accommodate future user growth.

JST has confirmed The PMRCL's Telecommunication Facility Plan is suitable and appropriate for the transportation capability based on traffic demand forecasts.

### (3) Procurement Feasibility Review from India and other countries (including Japan), Procurement Feasibility Review over the medium-to-long term

#### 1) Procurement Feasibility from India and other countries

**<Conformity with Regional Standards>**

PMRCL plans to conform to CENELEC Standards for some telecommunication facilities. CENELEC Standards are European Regional Standards. JST guessed it would be difficult for some suppliers to bid on the project if PMRCL plans to conform to CENELEC Standards. JST evaluates the construction cost issue is essential for PMRCL, and the construction cost could be lower if PMRCL could expand its methods of Procurement.

JST inquired why PMRCL plans to conform to the CENELEC Standard for some telecommunication facilities and received the following response.

- PMRCL's specifications provide CENELEC Standards or other recognized International Standards equivalent to CENELEC. However, if other recognized International Standards are followed in place of CENELEC, the required documents and certificates must be submitted and approved by PMRCL.

That means PMRCL can also accept other recognized International Standards, such as ISO and IEC.

JST has confirmed that PMRCL has considered Procurement Feasibility from around the world for its telecommunication facilities.

#### 2) Procurement Feasibility over the medium-to-long term

**<Various Facilities>**

PMRCL plans to conform to International Standards such as IEEE, IEC, etc., Standards equivalent to International Standards, and Regional Standards such as DoT of domestic Standards. PMRCL also plans to introduce telecommunication facilities that are proven or available worldwide or in India.

JST has confirmed that PMRCL has considered Procurement Feasibility over the medium-to-long term for its telecommunication facilities.

### (4) Appropriateness Review of Facility Flexibility and Stability

**<Various Facilities>**

PMRCL plans to introduce telecommunication facilities that are proven in India. PMRCL also plans to introduce durable fiber optic cables and redundant configuration for the backbone network of telecommunication facilities. In addition, Devices connected to the backbone network are required to be highly reliable and fault-tolerant. Therefore, these policies are expected to ensure stable data communications.

JST has confirmed that PMRCL has considered the Flexibility and Stability of its telecommunication facilities.

### (5) Proposals for Improvement

PMRCL plans to introduce the latest systems/devices/equipment available and standardized worldwide.

If PMRCL changes its plan to introduce an additional system/device/equipment or specification at the detailed design phase, an additional interface (including hardware or software) could be needed to connect with the existing system/device/equipment. In addition, the additional construction cost and procurement/construction period could be needed because systems/devices/equipment could be more complex. JST recommends that PMRCL introduces the systems/devices/equipment or specification within the scope of the current plan.

- Regarding this JST proposal, JST has received the comment from PMRCL that the majority of the systems/devices/equipment or specification shall be within the scope of the current plan at the detailed design phase.

PMRCL plans to use UPSs commonly for its signaling facilities (including the train control system), telecommunication facilities, and AFC system facilities. JST recommends PMRCL to use UPSs for facilities that could directly affect the train operation and UPSs for facilities that could not directly affect the train operation separately, with the perspective of stable train operation.

- Regarding this JST proposal, JST has received the following comments from PMRCL.
  - As per standard practice of DMRC from Phase 1/2/3 including Phase 4 projects, the UPS of S&T is designed and commissioned common for Signaling, Telecommunication, and AFC facilities keeping appropriate safety checks while designing to avoid failure of entire UPS due to fault in any other subsystems such as Telecommunication/AFC.
  - Hence, for Patna the Metro Rail Construction Project also, a common UPS system with physically separate feeding MCCBs of appropriate ratings at the output ACDB panel of the UPS system has been planned for Signaling, AFC, Telecommunication, and other critical services which are essential for train operation.
  - Also, using common UPS for Signaling facilities along with Signaling, AFC, Telecommunication, and other critical services which are essential for train operation, cost of the contract in terms of Supply, installation, and commissioning, and then in terms of regular maintenance cost shall be reduced.
- JST agrees with the PMRCL's UPS installation method, as the planned method will likely lead to acceptable and stable train operations and cost savings.

# 10. Fare Collection System

## 10.1 Overview of Existing Studies

### 10.1.1 AFC System Facilities

The main technical specifications of AFC System Facilities for PMRCL are shown in the below table.

**Table 10-1: The Main Technical Specifications of AFC System Facilities**

| Main System/Device/Equipment | The Main technical specifications |
|---|---|
| Central Computer<br>Station Computer<br>Automatic Fare Gate (AFG)<br>Ticket Office Machine (TOM)<br>Excess Fare Office (EFO)<br>Ticket Vending Machine (TVM)<br>Passenger Operated Machine (POM)<br>Ticket Reader (TR)<br>Portable Ticket Decorder | The main technical specifications of AFC System Facilities are planned as follows:<br>• Fare media<br>▪ NCMC (National Common Mobility Card)<br>- Contactless smart card<br>Interface Specification of NCMC Ecosystem Version 1.2<br>(Part IV to Part VII), CDAC, the Indian standard<br>- qSparc (quick Specification for Payment Application of RuPay Chip, NPCI, the Indian standard)<br>- NCMC recharge using cash, debit/credit card, and Netbanking/web portal<br>▪ Quick Response (QR) ticket<br>- Paper or mobile<br>(QR Ticketing System for Transit Operators -Specifications (v1.1)-, CDAC, the Indian standard)<br>▪ NFC IP-1 (ISO/IEC 18092)<br>• AFC System Facilities<br>▪ All devices at the station (AFG, TOM/EOF, TVM/POM, etc.) are connected to the Station Computer with the local station network.<br>▪ All station computers are connected to the Central Computer with backbone optical fiber cables.<br>▪ Up to 256 Station Computers can be connected to the Central Computer.<br>▪ Retractable flap gate<br>- Entry gate<br>- Exit gate<br>- Swing barrier ( for disabled people)<br>▪ 25 passengers per minute per gate as AFG capacity |

Source: DPR, JST

### 10.1.2 Others

The uninterrupted power supply (UPS) is planned to be commonly used for Train Control Systems (CBTC), Signaling Facilities, Telecommunication Facilities, and AFC systems and supply power backup for about 2 hours.

## 10.2 Reviews of Existing Studies and Proposals for Improvement

### 10.2.1 Conformity Review with International Standards/Regional Standards and Appropriateness Review of Facility Plan

**Table 10-2: International/Regional Standards adopted for PMRCL's AFC system facilities**

| The main International/Regional Standards | | | | | Remark |
|---|---|---|---|---|---|
| | | International Standards+ | Regional Standards | | |
| | | | Overseas | Domestic | |
| Automatic Fare Collection (AFC) System | Interface Specification of NCMC Ecosystem Version 1.2 (Part IV to Part VII) 1 | (✓) | | ✓ | • The Rupay Chip is mounted on the fare media based on Type-A (ISO/IEC 14443) and EMV (Europay, Master, VISA: The credit-card companies standard) |
| | qSparc (quick Specification for Payment Application of Rupay Chip) | | | ✓ | |
| | ISO/IEC 18092 (IP-1) | ✓ | | | • NFC (Near Field Communication) |

+ "International Standards" in the table also include standards established by international parties and companies.

Source: JST

#### (1) Conformity with International Standards/Regional Standards

**<Possibility of being restricted by International/Regional Standards>**

JST has confirmed that PMRCL's AFC system facilities would have few constraints imposed by International Standards or by Regional Standards established by Regional Authorities, the Indian Ministry of Railways, related Authorities, etc., for the following reasons.

- PMRCL's AFC system facilities are equivalent to or similar to those proven in India.
- PMRCL's AFC system facilities are planned considering International Standards or Regional Standards established by Regional Authorities, the Indian Ministry of Railways, related Authorities, etc.

JST has also confirmed that PMRCL has recognized that PMRCL's AFC system facilities aren't restricted to International/Regional Standards.

JST has confirmed that PMRCL's AFC system facilities have adopted appropriate International/Regional Standards.

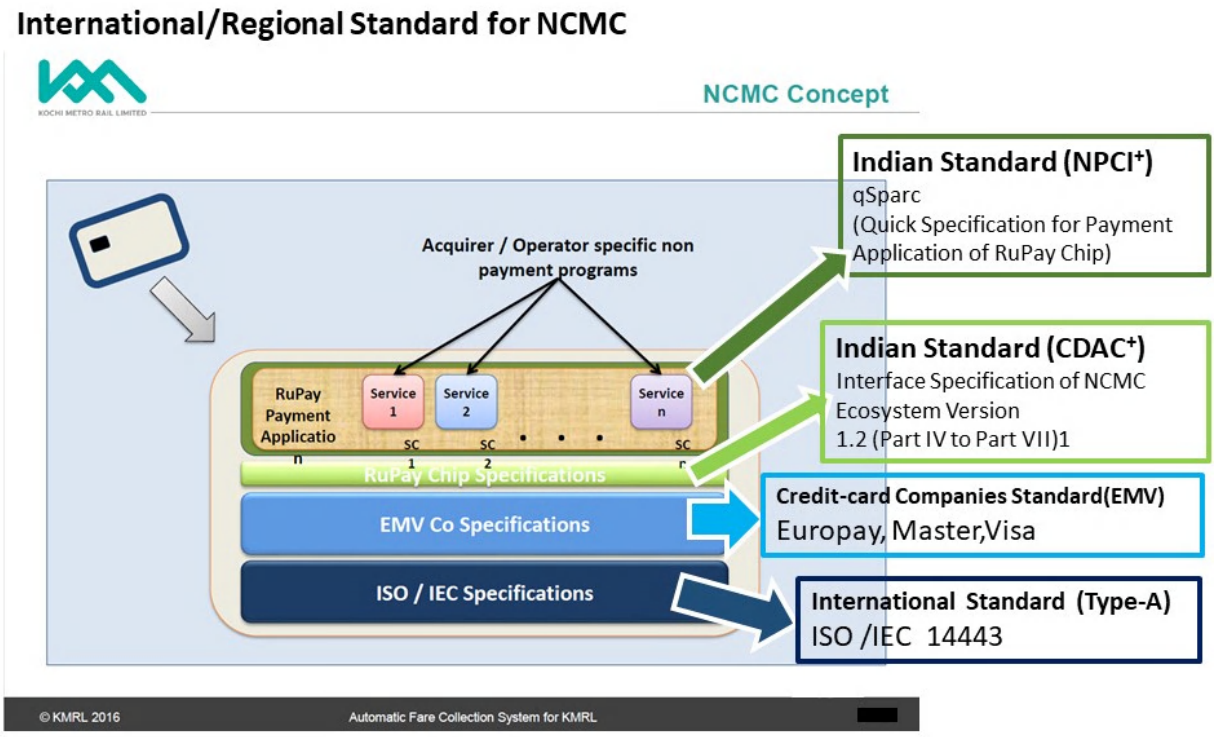
JST recommends that PMRCL work on the project after confirming the conformity with International/Regional Standards if PMRCL changes The AFC System Facility Plan at the detailed design phase.

## (2) Appropriateness of Facility Plan

**<NCMC>**

JST has confirmed PMRCL plans to introduce the open-loop AFC System using NCMC (National Common Mobility Card), Indian public transportation standard fare media, to achieve full interoperability, "One Nation One Card."

JST has also confirmed that the Rupay Chip (Interface Specification of NCMC Ecosystem) is mounted on the fare media based on Type-A (ISO/IEC 14443) and EMV (Europay, Master, VISA: The credit-card companies standard) and that NCMC is activated by the dedicated app (qSparc: Indian standard)




+CDAC: Centre for Development of Advanced Computing
+NPCI: Nation Payment Corporation of India

Source: UNBUNDLING FOR PPP, Automatic Fare Collection System for KMRL, PRAVEEN GOYAL (Kochi metro Director (System)), JST (Add comment)

**Figure 10-1: International/Regional Standard for NCMC**

The comparison of the AFC system using only NCMC, which PMRCL plans to introduce, and the AFC system using NCMC and FeliCa is shown in the following figure.

**Fare Media Brands and Features**

| | (Nationwide/Local Card) NCMC  | (Nationwide Card) NCMC + Combined Usage (Local Card) FeliCa  | 【Reference】 FeliCa  |
|---|---|---|---|
| International /Regional Standard | ○NCMC (Open-loop)<br>・Interface Specification of NCMC Ecosystem Version 1.2 (Part IV to Part VII), CDAC, the Indian standard based on Type-A (ISO/IEC 14443) and EMV (Europay, Master, VISA: The credit-card companies standard)<br>・qSparc, quick Specification for Payment Application of RuPay Chip, NPCI, the Indian standard<br>・ISO/IEC 18092 (NFC IP-1)<br>○FeliCa (Closed-loop)<br>・ISO/IEC 18092 (NFC IP-1) | | |
| Automatic Fare Gate Capacity | About 30 people per minute per gate | About 30 to 60 people per minute per gate+<br>+It depends on the Fare Media Brand. | About 60 people per minute gate |
| Construction Cost | 1 | 1.05～1.1++<br>++The construction cost could be reduced because the number of Automatic Fare Gates can be reduced due to Automatic Fare Gate Capacity increase compared to NCMC installations. | 1 |
| Usage Example in India | (SBI Bank)<br>Nagpur Metro<br>Noida Metro<br>(Axis Bank)<br>Kochi Metro | ・Ahmedabad Metro (Phase-1)<br>Line 1, Line2 (FeliCa: Not in operation)<br>・Chennai Metro<br>(Phase-1 including extension)<br>Line1, Line2 | – |

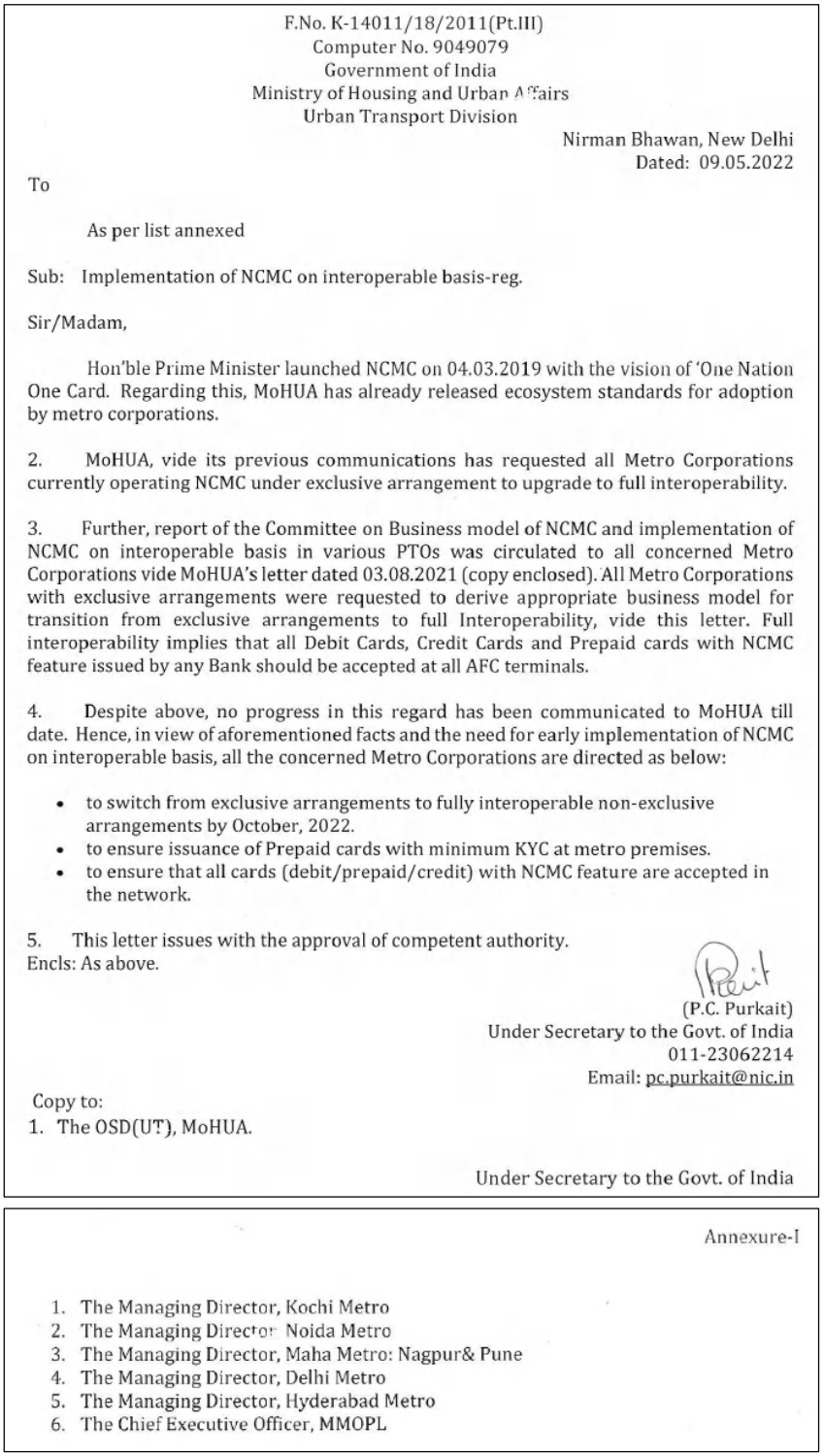
Source: JST

**Figure 10-2: Fare Media Brands and Features**

JST has confirmed that PMRCL plans the Automatic Fare Gate (AFG) capacity as 25 people per minute per gate, and JST has guessed the AFC system using only NCMC would be more reasonable for PMRCL.

JST has also confirmed that The PMRCL's AFC system facilities are equivalent to or similar to those proven worldwide or in India.

In addition, JST has guessed that Indian-related metro corporations will modify their AFC systems to adapt to NCMC (Type-A and EMV, qSparc) because they have been strongly requested by the Indian-related authority (MoHUA) to achieve full interoperability by NCMC



F.No. K-14011/18/2011(Pt.III)
Computer No. 9049079
Government of India
Ministry of Housing and Urban Affairs
Urban Transport Division

Nirman Bhawan, New Delhi
Dated: 09.05.2022

To

As per list annexed

Sub: Implementation of NCMC on interoperable basis-reg.

Sir/Madam,

Hon'ble Prime Minister launched NCMC on 04.03.2019 with the vision of 'One Nation One Card. Regarding this, MoHUA has already released ecosystem standards for adoption by metro corporations.

2. MoHUA, vide its previous communications has requested all Metro Corporations currently operating NCMC under exclusive arrangement to upgrade to full interoperability.

3. Further, report of the Committee on Business model of NCMC and implementation of NCMC on interoperable basis in various PTOs was circulated to all concerned Metro Corporations vide MoHUA's letter dated 03.08.2021 (copy enclosed). All Metro Corporations with exclusive arrangements were requested to derive appropriate business model for transition from exclusive arrangements to full Interoperability, vide this letter. Full interoperability implies that all Debit Cards, Credit Cards and Prepaid cards with NCMC feature issued by any Bank should be accepted at all AFC terminals.

4. Despite above, no progress in this regard has been communicated to MoHUA till date. Hence, in view of aforementioned facts and the need for early implementation of NCMC on interoperable basis, all the concerned Metro Corporations are directed as below:

- to switch from exclusive arrangements to fully interoperable non-exclusive arrangements by October, 2022.
- to ensure issuance of Prepaid cards with minimum KYC at metro premises.
- to ensure that all cards (debit/prepaid/credit) with NCMC feature are accepted in the network.

5. This letter issues with the approval of competent authority.
Encls: As above.

(P.C. Purkait)
Under Secretary to the Govt. of India
011-23062214
Email: pc.purkait@nic.in

Copy to:
1. The OSD(UT), MoHUA.

Under Secretary to the Govt. of India

Annexure-I

1. The Managing Director, Kochi Metro
2. The Managing Director Noida Metro
3. The Managing Director, Maha Metro: Nagpur& Pune
4. The Managing Director, Delhi Metro
5. The Managing Director, Hyderabad Metro
6. The Chief Executive Officer, MMOPL

Source: PMRCL

**Figure 10-3: The letter issued by MoHUA Urban Transport Division to strongly request to adapt to NCMC (Dated:09.05.2022)**

JST has confirmed that there would be no technical concerns and requirements PMRCL couldn't solve without introducing FeliCa. Therefore, JST has confirmed that The PMRCL's AFC System Facility Plan is appropriate.

### 10.2.2 Appropriateness Review of Facility Plan suitable for the transportation capability based on traffic demand forecasts

**<NCMC>**

PMRCL plans the capacity of the Automatic Fare Gate (AFG) as 25 people per minute per gate.
PMRCL planned the capacity of the AFG as 35 people per minute per gate in DPR.

JST inquired about why PMRCL changed the number of people from 35 to 25 and received the following response.

- 25 People per gate per minute is operation throughput based on experience in DMRC.

JST has reviewed PMRCL's policies and confirmed The PMRCL's Facility Plan is suitable and appropriate for the transportation capability based on traffic demand forecasts.

### 10.2.3 Procurement Feasibility Review from India and other countries (including Japan), Procurement Feasibility Review over the medium-to-long term

**<Various Facilities>**

PMRCL plans to conform to International Standards such as IEC, etc., or Regional Standards such as domestic Standards of CDAC and NPCI.

PMRCL also plans to introduce AFC system facilities that are proven or available worldwide or in India.

JST has confirmed that PMRCL has considered Procurement Feasibility from around the world and over the medium-to-long term for its AFC system facilities.

### 10.2.4 Appropriateness Review of Facility Flexibility and Stability

**<Various Facilities>**

PMRCL plans to introduce AFC system facilities that are proven worldwide or in India.

JST has confirmed that PMRCL has considered the Flexibility and Stability of its AFC system facilities.

### 10.2.5 Proposals for Improvement

PMRCL plans to use UPSs commonly for its signaling facilities (including the train control system), telecommunication facilities, and AFC system facilities.

JST recommends PMRCL to use UPSs for facilities that could directly affect the train operation and UPSs for facilities that could not directly affect the train operation separately, with the perspective of stable train operation.

- Regarding this JST proposal, JST has received the following comments from PMRCL.
  - As per standard practice of DMRC from Phase 1/2/3 including Phase 4 projects, the UPS of S&T is designed and commissioned common for Signaling, Telecommunication, and AFC facilities keeping appropriate safety checks while designing to avoid failure of entire UPS due to fault in any other subsystems such as Telecommunication/AFC.

- Hence, for the Patna Metro Rail Construction Project also, a common UPS system with physically separate feeding MCCBs of appropriate ratings at the output ACDB panel of the UPS system has been planned for Signaling, AFC, Telecommunication, and other critical services which are essential for train operation.
- Also, using common UPS for Signaling facilities along with Signaling, AFC, Telecommunication, and other critical services which are essential for train operation, cost of the contract in terms of Supply, installation, and commissioning, and then in terms of regular maintenance cost shall be reduced.

➢ JST agrees with the PMRCL's UPS installation method, as the planned method will likely lead to acceptable and stable train operations and cost savings.

# 11. Rolling Stock

## 11.1 Overview of Existing Studies

### 11.1.1 Route and Rolling Stock Plan

The target corridors are the two corridors (total 32.1km), as shown in the next table. These lines' characteristics are track gauge of 1,435mm, traction system of AC25kV 50Hz overhead collection system, and maximum gradient 4% for mainline.

Rolling stock dimensions are the length of 22m class, the width of 3.2m in DPR (PMRCL changed to 2.9m based on MOHUD guideline in July 2022), 3 cars or 6 cars of train configuration. Requested number of cars are 102 cars at the opening (2024), as shown in the next table.

Signal system in CBTC and PSD is installed at part of the stations.

**Table 11-1: Rolling Stock Required**

| Corridor | km | Train | Car | Remarks |
|---|---|---|---|---|
| Corridor 1<br>Danapur – Khemni Chak | 17.9 | 3 cars 14<br>6 cars 3 | 60 | Underground : 10.5km<br>Elevated : 7.4km |
| Corridor 2<br>Patna Station – New ISBT | 14.1 | 3 cars 14 | 42 | Underground : 8.0km<br>Elevated : 6.1km |
| **Total** | **32.7** | **53** | **102** | |

Source: DPR

### 11.1.2 Technical Details

The next table shows the technical details of rolling stock.

## Table 11-2: Technical Details of Rolling Stock

| Item | Dimension | |
|---|---|---|
| Track Gauge | 1,435mm | |
| Traction System | AC25kV 50Hz Overhead Collection System | |
| Train Configuration | 6 cars train: DMC + TC + MC + MC + TC + DMC, 3 cars train: DMC + TC + DMC<br>(notation in Japan: Mc – T – M – M – T – Mc, Mc – T – Mc ) | |
| Car Body Material | Stainless Steel or Aluminium | |
| Car Dimension | Width of Body | 2.9m (3.2m in DPR) |
| | Length of Body | DMC approx. 21.0m<br>TC, MC approx. 20.5m |
| | Maximum Length over Coupler 22m | |
| | Height of Body<br>Height of Floor | 3.9m<br>1100mm (crush load) |
| Passenger Loading | Design of Traffic 6 passenger/m²<br>Design of Propulsion System 8 passenger/m²<br>Design of Mechanical Strength 10 passenger/m² | |
| Passenger Capacity<br>(@ 6 passenger/m²) | DMC<br>TC, MC<br>6 cars train | 252 (seating: 42, standing: 210)<br>268 (seating: 50, standing: 218)<br>1,576 (seating: 284, standing: 1292)<br>in DPR 282 (seating: 42, standing: 240)<br>298 (seating: 50, standing: 248)<br>1,756 (seating: 284, standing: 1472) |
| Weight | Tare Weight (max.) | DMC: 42.0 t, TC: 40.3 t, MC: 40.3 t<br>(DMC: 42.5 t, TC: 40.8 t, MC: 40.8 t in DPR) |
| | Passenger Weight | DMC: 16.4 t, TC: 17.4 t, MC: 17.4 t<br>(DMC: 18.3 t, TC: 19.4 t, MC: 19.4 t in DPR)<br>@6 passenger/m² (0.065 t/passenger) |
| | Gross Weight (max.) | DMC: 58.4 t, TC: 57.7 t, MC: 57.7 t<br>(DMC: 60.8 t, TC: 60.2 t, MC: 60.2 t in DPR)<br>@6 passenger/m² |
| Axle Load (max.) | 16 t (17 t in DPR) | (@ 8 passenger/m²) |
| Maximum Train Length | approx. 129.0 m | (6 cars train) |
| Maximum Speed | Design Speed<br>Operation Speed | 90 km/h<br>80 km/h |
| Wheel Profile | UIC 510-2 | |
| Noise Limit | Qualitative Requirement | |
| Acceleration Rate | (Maximum) | 1.2 m/s² |
| Deceleration Rate | Max. Service Brake<br>Emergency Brake | 1.1m/s²<br>1.3 m/s² |
| Bogie and Suspension | Bolster Less Type | Air Suspension |
| Brake System | Electro-Pneumatic (EP) Service Friction Brake<br>Failsafe Pneumatic Emergency Friction Brake<br>Spring Actuated Air-release Parking Brake<br>Electric Regenerative Service Brake<br>Blending Function between EP and Regenerative brake<br>Anti-Skid Function<br>Disk Brake or Tread Brake | |

| Item | Dimension | |
|---|---|---|
| Coupler | Between Units | Automatic Coupler with Pneumatic and Electrical Coupling |
| | Front Cab end of DMC | Automatic Coupler with Pneumatic and Electrical Coupling |
| | Between Cars | Semi-Permanent Coupler |
| Emergency Door | Front Evacuation Door | |
| Passenger Doors | Bi-parting Sliding Door (Four Doors per Side) Electrical Control System | |
| Passenger Seats | Longitudinal Seats (Stainless Steel) | |
| Cooling of Equipment | Transformer<br>CI and APS<br>Traction Motor | Forced Cooling<br>Self or Forced Cooling<br>Self-Cooling |
| Control System | TCMS | |
| Propulsion System | VVVF inverter control (Switching device: IGBT)<br>Traction motor: Induction motor (16 motors in 4M2T 6cars train) | |
| HVAC | Cooling, Heating, and Humidifier<br>25℃ with 60% RH in Saloon | |
| PA*/PIS*/PSSS* | Requested | |
| Battery | Nickel Cadmium Type | |
| Headlight Type | LED | |
| Coasting in Operation | 8% (Run time in All-out mode +8%) | |
| Maximum Gradient | 3% (partly 4%) | |

Note: * PA: Passenger Address System, * PIS: Passenger Information Display System,
* PASS: Passenger Surveillance System (CCTV)

Source: PMRCL

### 11.1.3 Salient Features

#### (1) Train set

DMC : Driving Motor Car
MC : Motor Car
TC : Trailer Car

The standard car width of the Indian metro is 3.2m or 2.9m, this project is 3.2m for heavy traffic in DPR, but PMRCL changed to 2.9m based on MOHUD guideline in July 2022.

Car length is a 22m class, which is also as per Indian Metro standard. A cross-section is specified by a kinematic envelope, including oscillating the car body, and no static rolling stock gauge is specified as in Japan. (Refer to JIS E4041, 8.2.2.1A)

#### (2) Passenger Capacity

The following passenger capacity is defined for each purpose.

| | | |
|---|---|---|
| AW0 | No passenger (Tare weight) | |
| AW1 | Seated capacity | (Capacity in Japan) |
| | (3.3 passenger/m² + Seated) | 100% |
| AW2 | 4 passenger/m² + Seated | 115% |
| AW3 | 6 passenger/m² + Seated | 160% for design of traffic |

| | |
|---|---|
| AW4 8 passenger/m² + Seated | 210% for design of propulsion system |
| 10 Passenger/m² + Seated | 260% for design of mechanical strength |

#### (3) Weight

Maximum tare weight is 42 ton (42.5 ton in DPR), and maximum axle load is 16 ton at 8 passenger/m² (17 ton in DPR). It is a higher value than the example in Japan (less than 14 ton), but it is a traditional value in Indian Metro (AC25kV 50Hz) considering the European standard's crashworthiness

#### (4) Braking System

The service brake is a blending of an Electric-Pneumatic brake and a Regenerative brake. It can realize to save energy consumption by air-supplement control. Holding the brake in the dwelling is requested. Spring-applied parking brake is requested too.

#### (5) Propulsion System

VVVF inverter control system with IGBT as a switching device and the induction motor is a proven design for metro EMU worldwide.

#### (6) Fire

Fire protection is specified by European Standard EN45545 or equivalent.

#### (7) Crash Worthiness

Crashworthiness is specified by European Standard EN15227 or equivalent. The compressive strength of the car body is 800kN (in Japan 490kN).

### 11.1.4 Others

#### (1) Cost

The estimated price excluding tax for one car is INR 8.0 Cr (JPY approx.12.8 Cr) based on MOHU guideline.

#### (2) Schedule

There are no clear explanations, but as per the terms of the contract, the delivery is approximately 2 years.

## 11.2 Reviews of Existing Studies and Proposals for Improvement

### 11.2.1 3Corridor and Rolling Stock Plan

For Corridor1 (17.9km) and Corridor 2 (14.2km), the initial plans are 28 sets of “3 cars” trains and 3 sets of “6 cars” trains. There are no spare trains of “6-cars”, and it is impossible to operate “3+3 cars” train, because of front evacuation in an emergency situation. As stated in Table 8-5, 24 sets of “3 cars” trains and 5 sets of “6 cars” train are recommended.

### 11.2.2 Technical Features

It has a gauge of 1,435mm, a body width of 2900mm (3200mm in DPR), and an electrified system of AC25kV50Hz.

It follows the Delhi Metro Line 7 and 8 (so-called RS10 in the procurement category) except for body width.

Acceleration of 1.2m/s/s seems to be excessive, and further consideration will be done in the design stage.

### 11.2.3 Main Characteristic

3 cars are one unit, which is equipped with pantograph and main transformer on the intermediate T car and supplies power to the converter-inverter (VVVF inverter) of the M car on both side. It is the standard composition for MT ratio 67% Metro in India.

### 11.2.4 Cooling for CI and APS

The cooling system for CI (Converter/Inverter for propulsion system) and APS (Auxiliary Power Supply) should be self-cooling. Because forced air cooling causes noise and vibration, and maintenance for cooling system including dust filter is dirty and troublesome. It will be considered in design stage.

### 11.2.5 Preparation for Conversion of Train Configuration

As stated in 3.6 Train Operation Plan, 4 sets of “3 cars” trains will be converted to 2 sets of “6 cars” trains in the future (around 2041). Rolling stock design should be included preparation for conversion of train configuration. In particular DMC front design (converted from evacuation door to gang way) , unification of car length, and TCMS. It will be prepared in the design stage.

This method has many achievements in Japan, but there are not many example in India. When adding new cars in the middle of the train set, it is necessary to consider the unification of the system with existing cars.

# 12. Power Supply and Traction

## 12.1 Overview of Existing Studies

### 12.1.1 Power Supply Facilities

#### (1) Power Receiving Facilities

In power receiving equipment, power is received from the grid substation (GSS) of BSPTCL's power grid to receiving substation (RSS) owned by PMRCL. The voltage is lowered for each railway equipment such as the feeding line to supply traction loads for railways and auxiliary power supply for lights and power at stations and depots. Keeping in view of the reliability requirements and considering the complete length of corridors, two RSS are proposed to avail power supply from GSS at 132 kV voltage through cable feeders. The power supply of Mithapur RSS for corridor 1 is from Mithapur GSS and the Power of New ISBT RSS for corridor 2 is from the upcoming BSPTCL Switching Sub-Station (S/S) at New ISBT after its connectivity with LILO arrangement of Gaurichak-Fatuha transmission line.

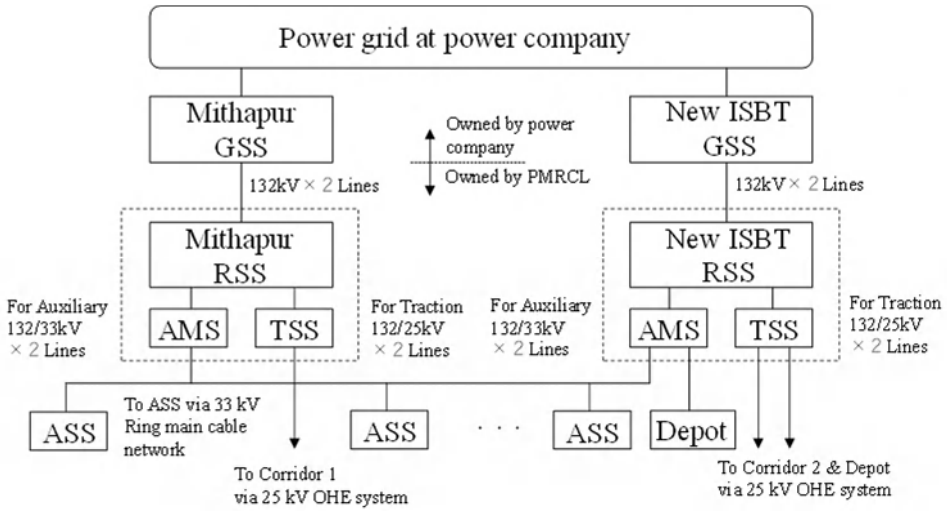
**Table 12-1: Sources of Power Supply**

| Grid sub-station | RSS of PMRCL | Feeding Zone | Distance from GSS to RSS |
|---|---|---|---|
| Mithapur GSS (132 kV) | Mithapur RSS (132/33/25 kV) | Corridor 1 | 0.3 km * |
| New ISBT GSS (132 kV) | New ISBT RSS (132/33/25 kV) | Corridor 2 | 0.3 km |

* Originally it was 0.5km, but the location was changed.

Source: DPR and JST

The power supply from GSS at 132 kV will be stepped down to 25 kV single phase-supply for traction and 33 kV 3-phase supply for auxiliary at each RSS cum TSS and AMS. The traction power will be fed to 25 kV OHE system through cable feeders and the auxiliary power will be distributed along the alignment through 33 kV Ring main cable network for feeding ASS. The structure diagram of the power-receiving equipment is shown in the following figure.




Source: JST

**Figure 12-1: The Structure Diagram of Power Receiving Equipment**

Each RSS requires backup facilities and parallel supply of loads from two RSSs. In normal conditions, Mithapur RSS will feed corridor 1 and New ISBT RSS will feed Corridor 2. In case either of the two RSS fails, then the other RSS will feed both the corridors. Under normal conditions, the power supply from each RSS is shared, and all power shall be available from the other RSS in emergency conditions such as one RSS failure. Therefore it is necessary for Each RSS to be of sufficient capacity. However, in case of total grid failure, all trains may come to a halt but emergency lighting, fire and other essential services can be catered to by stand-by UPS/ DG sets.

Based on emergency demand expected at each RSS, 2 traction transformers of 132/25 kV, 30 MVA capacity each at Mithapur RSS and New ISBT RSS are required. Similarly, two Auxiliary transformers of 132/33 kV, 30 MVA capacity each are proposed to be provided at both RSSs. The main equipment of possible installation in RSS is shown in the table below.

**Table 12-2: Main Equipment of Possible Installation in RSS**

| Field | Equipment of possible installation | | Remark |
|---|---|---|---|
| Power Supply, Traction | Mithapur RSS, New ISBT RSS (cum TSS/AMS) | Transformer (132/25 kV, Single-phase, 30 MVA, ONAN) | For use In Traction |
| | | Transformer (132/33 kV, 3-phase, 30 MVA, ONAN) | For use In Auxiliary |
| | | Switchgear (rated current 2000A) | For use In Traction |
| | | Switchgear (rated current 1250A) | For use In Auxiliary |

Source: DPR and JST

Electricity is required for operation of Metro system for running of trains, station services (e.g. lighting, lifts, escalators, signaling & telecom, firefighting, etc.) and workshops, depots & other maintenance infrastructure within the premises of metro system. The power requirements of a metro system are determined by peak-hour demands of power for traction and auxiliary applications. According to DPR, the power requirement for corridors is calculated by considering the following points.

- Train operation with a combination of 3 & 6 car rakes for the Danapur to Khemni Chak corridor.
- Train operation with 3 car rakes for Patna Junction to New ISBT corridor.
- Peak period headway of 3.0 minutes for both corridors.
- Specific energy consumption of rolling stock – 75 kWh / 1000 GTKM
- Regeneration at 30%
- At grade/ Elev. station load – initially 200 kW, ultimate design 300 kW
- Underground station load – initially 1500 kW, ultimate design 2000 kW
- Depot auxiliary load – initially 1500 kW, ultimate design 2000 kW
- Power factor of load – 0.9
- Transmission losses at 5%

Keeping in view of the above norms, the power demand estimation of DPR for the proposed metro corridors is given in the table below. According to this table, traction and auxiliary peak demands in normal operation are less than the capacity of a transformer of 30 MVA during the period respectively. And traction and auxiliary peak demands in an emergency situation of one side RSS failure are also less than double capacity of transformer of 30 MVA during the period respectively.

**Table 12-3: Power Demand Estimation**

| Name of RSS | Peak Demand – Normal (MVA) | | | | Peak Demand – Emergency (MVA) | | | |
|---|---|---|---|---|---|---|---|---|
| | 2024 | 2031 | 2041 | 2051 | 2024 | 2031 | 2041 | 2051 |
| Mithapur RSS (Corridor 1) | | | | | | | | |
| Traction | 6.75 | 10.12 | 10.91 | 14.01 | 12.03 | 16.77 | 18.05 | 22.08 |
| Auxiliary | 12.37 | 13.30 | 14.58 | 16.80 | 27.53 | 29.55 | 32.38 | 37.22 |
| **Total** | **19.12** | **23.42** | **25.49** | **30.81** | **39.56** | **46.32** | **50.43** | **59.30** |
| New ISBT RSS (Corridor 2) | | | | | | | | |
| Traction | 5.27 | 6.65 | 7.14 | 8.07 | 12.03 | 16.77 | 18.05 | 22.08 |
| Auxiliary | 15.17 | 16.25 | 17.79 | 20.42 | 27.53 | 29.55 | 32.38 | 37.22 |
| **Total** | **20.44** | **22.90** | **24.94** | **28.48** | **39.56** | **46.32** | **50.43** | **59.30** |

Source: DPR

As can be seen by the table below, the estimated power requirement and capacity here are similar to those for Chennai metro Phase-II with 25 kV AC feeding system. In terms of ASS, the transformer capacity in Patna metro is lower due to energy saving about LED for lighting and VRV system for Air-conditioning. Therefore JST thinks that the capacity of transformer is appropriate. By the way, as the underground stations power at two auxiliary substations is planned from two different sources, therefore, the tunnel ventilation system is not considered on DG set and the DG size for underground station is 380 kVA.

**Table 12-4: Comparison of Power Requirement and Main Equipment Capacity**

| | Patna Metro | Chennai Metro *1 |
|---|---|---|
| Power Requirement | Power Consumption of Rolling Stock:<br>75 kWh/1,000 GTKM<br>Regeneration:<br>30%<br>Power Consumption of Elevated Station:<br>Initially 200 kW, 2051yr 300 kW<br>Power Consumption of Underground Station:<br>Initially 1,500 kW, 2051yr 2,000 kW<br>Power Consumption of Depot:<br>Initially 1,500 kW, 2051yr 2,000 kW | Power Consumption of Rolling Stock:<br>70 kWh / 1,000 GTKM<br>Regeneration:<br>30%<br>Power Consumption of Elevated Station:<br>Initially 200 kW, 2055yr 300 kW<br>Power Consumption of Underground Station:<br>Initially 1,000 kW, 2055yr 1,500 kW<br>Power Consumption of Depot:<br>Initially 1,500 kW, 2055yr 2,000 kW |
| RSS/TSS/AMS | 2 nos.:<br>Mithapur RSS, New ISBT RSS<br>TSS : 132/25 kV 30 MVA<br>AMS : 132/33 kV 30 MVA | 12 nos.:<br>Madhavaram RSS, Vasanthi RSS, YMCA RSS, Tharamani RSS, Siruseri RSS, Nadhamuni RSS, Mugalivakkam RSS, St. Thomas RSS, Medavakkam RSS, Perubakkam RSS, CMBT RSS, Kodambakkam RSS<br>TSS : 110/25 kV 21.6 MVA or 30/42 MVA<br>AMS : 110/33 kV 31.6 MVA/40 MVA |
| ASS | Elevated : 315 kVA or 500 kVA<br>Underground : 2,500 kVA<br>Depot : 2 × 2,500 kVA | Elevated : 500 kVA<br>Underground : 3,200 kVA<br>Depot : 2 × 2,500 kVA |
| DG | Elevated :1 × 160 kVA<br>Underground :1 × 380 kVA<br>Depot :1 × 750 kVA | Elevated : 250 kVA<br>Underground : 2 × 910 kVA<br>Depot : 2 × 320 kVA |

*1 Comprehensive Detailed Project Report for Chennai Metro Phase-II, Dec., 2018

Source: DPR and JST

It is possible for the rated current of the switchgear to evaluate the value from comparing the estimated loads with the rated breaking capacity.

Rated Breaking Capacity (Traction): $P_{TSS}$ = 25 k [V] × 2,000 [A] = 50 M [VA]
Rated Breaking Capacity (Auxiliary): $P_{AMS}$ = √3 × 33 k [V] × 1,250 [A] = 71 M [VA]

The rated breaking capacity of the above is more than traction and auxiliary loads. Therefore JST thinks that the selection of the rated current is appropriate.

### (2) Feeder equipment

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

- 750 V DC : Third Rail System
- 1,500 V DC : Third Rail/ Overhead Catenary System
- 25 kV AC : Simple feeding system/ BT feeding System

Each feature of traction system is shown in the table below. The selection of proper traction system has a significant 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 metro system.

**Table 12-5: Feature of Traction System**

| Item | DC feeding system | | AC feeding system |
|---|---|---|---|
| Supply voltage to the Rolling Stock | 750 V<br>(Third Rail System) | 1,500 V<br>(Third Rail/<br>Overhead Catenary System) | 25 kV<br>(Simple feeding system/<br>BT feeding System) |
| Transportation Capability | 60,000 PHPDT | 60,000 ~ 80,000 PHPDT | 60,000 ~ 100,000 PHPDT |
| Substation Distance | 1-2 km | 3-10 km | 50 km (Simple feeding system)<br>30 km (BT feeding System) |
| Operation example in India | Kolkata<br>Bangalore<br>Kochi | Guangzhou<br>Shenzhen | Delhi<br>Jaipur<br>Chennai<br>Hyderabad<br>Indian Railways |
| Aesthetic (Elevated) | Good | Good (Third Rail)<br>Bad (Overhead Catenary System) | Bad |
| Initial Cost | High | High | Low |
| Voltage Drop | Big | Middle | Small |
| Energy Efficiency | Low | Middle | High |
| Risk of Electrical Shock | Big | Big (Third Rail)<br>Small (Overhead Catenary System) | Small |
| Possible Problem | Electrical Corrosion | Electrical Corrosion<br>Lightning Hazard | Inductive Interference<br>Lightning Hazard |

Source: DPR and JST

25 kV AC is the most economical followed by 1500 V DC and 750 V DC traction systems both from initial cost point of view as well as energy efficiency. But from the aesthetic point of view, 750 V DC Third rail

system is better. 25 kV AC system has the ability to carry a high traffic at a reduced cost with higher efficiency of operation. Considering the techno-economic advantages offered by 25 kV AC system, it is proposed to adopt 25 kV AC system for Patna metro. Then the feature of traction system is shown in the table below. From the table, using overhead contact lines at the elevated section and overhead rigid conductors at the underground section gives various advantages. The traction system in DPR is similarly proposed like this.

**Table 12-6: Characteristics of Electric Contact Line System**

| | Overhead Contact Lines | Overhead rigid Conductor |
|---|---|---|
| Current Collection Performance | Stable current collection at high speeds | The pantograph is less compliant than the overhead lane<br>Necessary parts to be supported in the upper part such as tunnel |
| Operating Speed | Up to about 300 km/h | Up to about 90 km/h |
| Maintenance and Management | Maintenance for contact line equipment involves work at heights.<br>Easy track maintenance | Easy to maintain contact line equipment and track |
| Electric Shock Accident | Too few | Too few |
| Investment Costs | Low for initial capital investment | Slightly higher for initial capital investment |
| Impact of Natural Disasters | The high impact of strong winds and earthquake | Depend on the location |
| Route Conditions | Since electrical separation is required above the Rolling Stock; a certain support height is required. | Since the small required electrical separation above the Rolling Stock allows slightly smaller tunnel diameters<br>Continuous support to the structural shed, such as a tunnel, is required. |
| Section to be adopted | To be adopted in various sections | Mainly tunnel section |

Source: JST

As for the feeding system, the simple feeding system will be adopted among the AC feeding system. The proposed simple feeding system here consists of contact wire, rail and return conductor. The feature of simple feeding system is very economical due to be the circuit construction simply. On the other hand, because return current flows into both rail and return conductor, leakage current causes the inductive interference of the communication line and rail potential is higher than other feeding systems.

The proposed 25 kV Rigid OHE system in underground section is similar to the one installed in underground sections of Delhi Metro. 25 kV Rigid OHE system comprises a hollow Aluminum Conductor Rail of adequate cross section with 150 $mm^2$ copper contact wire held with elastic pinch. The Al conductor rail is supported by an insulator and cantilever arrangement attached to drop-down supports fixed to tunnel roof. The supports are located at every 10 meters and there is no tension in the conductors and hence, no tensioning equipment is required in tunnel. The design of 25 kV rigid OHE system shall be in accordance to electrical clearances and contact wire height as per IEC 60913 and EN50122, which is summarized below.

- Contact wire height 4,318 mm in tunnel
- Structure to Live parts clearances 270/170/150mm (Static/Dynamic/Absolute min dynamic)
- Vehicle to Live parts clearances 290/190/150mm (Static/Dynamic/Absolute min dynamic)

The main equipment of possible installation in the traction equipment is shown in the table below.

**Table 12-7: Main Equipment of Possible Installation in Traction Equipment**

| Field | Equipment of Possible Installation | | Remark |
|---|---|---|---|
| Power Supply, Traction | Contact Line System | Flexible OHE (Contact wire 150 $mm^2$ Cu-Ag) | Elevated |
| | | (Catenary wire 120 $mm^2$ Cu-Mg) | |
| | | (RC 233 $mm^2$ ACC) | |
| | | (ATD Spring type/ Balance weight type) | |
| | | Rigid OHE (Contact wire 150 $mm^2$ Cu) | Underground |
| | | (Conductor Aluminium) | |
| | Feeding Post | 3 nos (Mithapur, New ISBT, Depot) | |
| | Sectioning Post | 1 no (Mithapur Station) | Corridor 1 |
| | Sub Sectioning and Paralleling Post, Sub Sectioning Post | 6 nos (CH: 0.086 km, 0.513 km, 2.94 km, 7.90 km, 13.950 km, 16.93 km) | Corridor 1 |
| | | 7 nos (CH: 0.375 km, 6.30 km, 8.69 km, 9.69 km, 10.106 km, 13.50 km, 14.064 km) | Corridor 2 |

Source: DPR and JST

### (3) Auxiliary power supply equipment

The auxiliary power will be required for the following.

- Lights & fans for station
- Service Buildings
- Foot over Bridges/ Subways
- Maintenance Depots
- Air-conditioning
- Lifts
- Escalators
- Water Supply Pumping Stations – for washing, toilets as well as fire protection measures.
- Equipment – Signaling, Telecom, Automatic Fare Collection, etc.

ASSs are envisaged to be provided at each station for stepping down 33 kV supply to 415 V for auxiliary applications. The ASS will be located at mezzanine or platform level inside a room. The demand of power at each elevated station is expected to be about 200 kW in the initial years and is likely to reach 300 kW in 2051. Similarly, for the underground stations, the auxiliary load requirements have been assessed at 1500 kW for the underground station which is likely to increase to 2,000 kW in 2051.

Two transformers of 315 kVA or 500 kVA of dry-type cast resin transformer at each elevated ASS for the elevated stations is proposed to be installed. One transformer of 2,500 kVA at each underground ASS for the underground stations is proposed to be installed. Apart from stations, separate ASS is required at depot with two transformers of 2,500 kVA to cater to depot cum workshop load. The main equipment of possible installation in the auxiliary equipment is shown in the table below.

**Table 12-8: Main Equipment of Possible Installation in Auxiliary Equipment**

| Field | Equipment of Possible Installation | | | Remark |
|---|---|---|---|---|
| Power Supply, Traction | 33kV Ring Main Network | Cable | (3R × 1C × 400 mm$^2$, 33 kV XLPE insulated FRLS) | Elevated |
| | | Cable | (3R × 1C × 400 mm$^2$, 33 kV XLPE insulated FRLSOH) | Underground |
| | ASS | Transformer | (33 kV/415 V, 3-phase, 315 kVA or 500 kVA, dry type cast resin transformer) | Elevated (12 nos) |
| | | Switchgear | (HT, LT) | |
| | | DG | (180 kVA) | |
| | | Transformer | (33 kV/415 V, 3-phase, 2,500 kVA) | Underground (12 nos × 2*) *2nos for 1 Station |
| | | Switchgear | (HT, LT) | |
| | | DG | (380 kVA) | |
| | | Transformer | (33 kV/415 V, 3-phase, 2,500 kVA) | Depot (1 no) |
| | | Switchgear | (HT, LT) | |
| | | DG | (320 kVA) | |
| | LT load system (LT Power Distribution, Illumination System, Lifts and Escalators, Fire Detection and Alarm System, Fire Suppression, etc. ) | | | |

Source: DPR and JST

Specifications of auxiliary loads are assumed as follows.

**Table 12-9: Specifications of Auxiliary Loads**

| Items | Specifications |
|---|---|
| **LT Power Distribution** | Main technical specifications are planned as follows<br>• 33kV power supply is stepped down to 415V, 3-phase for distribution to consumption points<br>• Composed of Lifts, Escalators, Light & power sockets, Fire system, VAC system and Signal & Telecom system, etc.<br>Normative Reference<br>• Low voltage power distribution cables shall comply with IEC 60502 or another applicable international standard<br>• Fire resistant cables shall be used for safety purpose and comply with performance requirements of IEC 60331 and BS 6387. |
| **Illumination System** | Main technical specifications are planned as follows<br>• For Illumination generally, all lighting fixtures shall be applied with 240V, single phase 50Hz power supply<br>• Use of LED light fixtures is recommended at elevated and underground stations of corridor and office buildings of depot due to Energy savings, lower life cycle cost, longer life span, rugged nature etc.<br>Normative Reference<br>• Type and quality of fittings and their luminous intensity shall relate to space being illuminated and will take into account effect of architectural space concept and color scheme as per IS 3646 |
| **Lift and Escalator** | Main technical specifications are planned as follows<br>• Lifts are machine-room less type lifts with gearless drive and 3-phase VVVF drive<br>• Escalators are heavy-duty public services escalators with 3-phase VVVF drive<br>• Further, the escalators will be provided with infrared sensors to automatically reduce the speed (to idling speed) when not being used |
| **Fire Detection and Alarm System** | Normative Reference<br>• Fire Detection and Alarm System shall be in conformance to applicable NFPA standard or Other International Standards and also comply with codes of practice, standards, regulations and requirements of PMRCL |

| Items | Specifications |
|---|---|
| **Fire Suppression** | Main technical specifications are planned as follows<br>**a) Portable Fire Extinguishers**<br>• Portable fire extinguishers shall be installed at all the stations<br>• Extinguishers shall be conspicuously located in positions where they will be readily accessible and immediately available in the event of fire<br>• Extinguishers shall be located near to room exits, corridors, stairways, lobbies and landings<br>• Extinguishers shall be installed at a height of 1 meter above floor level and shall be placed in a manner such that extinguisher operating instructions face outward<br>Normative Reference<br>• Complied with relevant IS Codes and codes of practice, standards, regulations and requirements of PMRCL<br>• Location and design of extinguisher cabinets provided shall comply fully to local fire authority requirements.<br>**b) Wet Mains System**<br>• Wet mains system is charged by the Fire pumps set<br>• Fire pump set shall have dual power supply and system shall be designed to achieve a pressure of 3.5 Bar in Elevated stations and 6.9 Bar in Underground stations at remotest fire hydrant point.<br>Normative Reference<br>• Fire Fighting wet mains system shall be based on NFPA-13, NFPA-14 and NBC<br>• System will draw water from fire water storage tank provided near station building based on NBC requirements<br>**c) Fire Hose Cabinets**<br>Normative Reference<br>• Fire Hose Cabinets shall be provided as per NBC and fire authority regulations in internal and external public areas of the station.<br>**d) Fire Hose Reels**<br>• Hose-reel shall be provided in such a way that it covers entire Concourse/ Platform areas with suitable number of fire hose cabinets<br>• Hose reels system will be based on direct feed from the Fire Water Wet mains<br>• Hose-reels shall be of the swing-recessed type<br>• Each hose-reel shall be an integral unit consisting of a stop valve, reel, hose, and shut-off assembly<br>• Hose reel shall be designed so as to facilitate swift withdrawal of hose in any direction with reel axis horizontal<br>Normative Reference<br>• Hose reels shall meet the requirements of IS 12585.<br>**e) Gas Flooding System**<br>• Gas Flooding System is proposed to be provided for protection of equipment in RSS, AMS, TSS, ASS and S&T equipment in Depot Control Centre or Operational Control Centre<br>Normative Reference<br>• Design of system shall be in conformance to NFPA standards |
| **Standby Diesel Generator (DG) Sets** | Main technical specifications are planned as follows<br>• It is proposed to provide standby DG set of 160kVA at all elevated stations and 380kVA at underground stations to cater to the following essential services<br>- Lift Operation<br>- Essential Lighting<br>- Signaling & Telecommunications<br>- Firefighting System<br>- Fare Collection System<br>• Silent type of DG sets, which have low noise levels and do not require separate room for installation<br>• UPS with adequate power backup may be installed for the very essential lighting load. |

Source: DPR

### 12.1.2 Mechanical Facilities

#### (1) Ventilation and Air Conditioning Facilities

System configuration of Ventilation and Air-Conditioning

According to the DPR, ventilation and air-conditioning equipment are used everywhere, i.e. elevated, at grade, underground section, and Depot. Ventilation and Air Conditioning systems (VAC systems) are planned for Station Air-conditioning Systems, Ventilation System for station plant rooms, Station Smoke Management Systems, Tunnel Ventilation Systems (TVS), and monitoring and control systems. The Station Track-way area are equipped with Trackway Exhaust System (TES) and Tunnels are provided with Tunnel Ventilation System (TVS).

Underground stations of the corridor are especially built in a confined space. A large number of passengers occupy concourse halls and the platforms, specifically 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 the following.

- 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 quantities of heat dissipated by the train equipment like traction motors, braking units, compressors mounted below the underframe, lights and fans inside the coaches, A/c units, etc.
- Removing vapours 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.

Furthermore, a large quantity of heat generated in underground station 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.

The design conditions of the VAC system are in the table below. Outside ambient conditions are as per ISHRAE-2017.

**Table 12-10: VAC System Design Requirements**

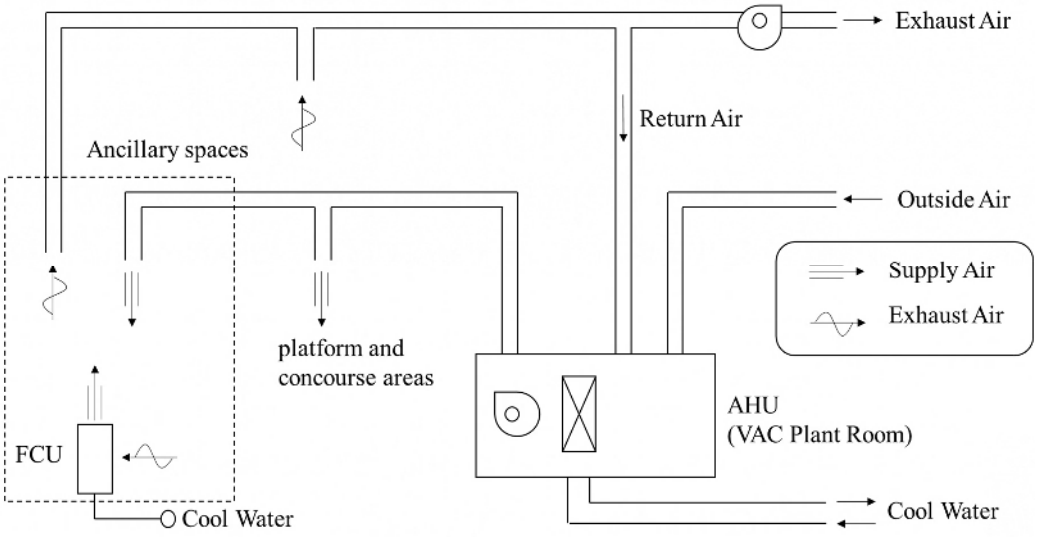
| Item | Plan |
|---|---|
| Ambient air conditions | Summer : 39.5℃ (DB) 23.4 ℃ (WB)<br>Rainy season : 33.0℃ (DB) 28.6 ℃ (WB)<br>※DB (Dry-bulb temperature) : Dry bulb temperature<br>WB (Wet-bulb temperature) : Wet-bulb temperature |
| Indoor conditions | Platform Concourse: 27°C at 55% RH<br>※ RH (Relative Humidity): Relative Humidity |
| Tunnel conditions | Usual maximum : DB 40℃<br>Maximum during congestion : DB 45℃ |
| Minimum fresh air | 10% or 18 cmh/person (station public)<br>※ Cmh (cubic meter per hour): Blower capacity, cubic-rice/hour ($m^3$/h) |

Source: DPR

Station Ventilation and Air Conditioning of ancillary spaces

Platform and Concourse public areas will be air-conditioned using supply air handling unit (AHU) located in air-handling plant rooms and ancillary areas will be air-conditioned using 16 of fan coil units (FCUs) located inside the ancillary room as shown in Figure 12-2. Each platform will be served by at least two separate air handling units with the distribution systems combined along each platform to ensure coverage of all areas in the event of single equipment failure. These air conditioning systems mix return air with the desired quantity of outside air.

Ancillary spaces such as staff room, and equipment plant room, will be mechanically ventilated or air conditioned in accordance with the desired air change rates and temperatures or humidity. All ancillary areas that require 24-hour air conditioning will be provided with fan-coil units. During the revenue hours when the main chilled water system is running the FCU will be used for air-conditioning. In non-revenue hours, small capacity air cooled scroll chillers will be operated.




Source: JST

**Figure 12-2: Station Ventilation and Air Conditioning System Scheme**

Specifications of AHU and FCU are assumed as follows.

**Table 12-11: Specifications of AHU and FCU**

| Items | Specifications |
|---|---|
| **AHU** | Main technical specifications are planned as follows<br>• Outside air requirement is based on occupancy, 7.5 cfm/person and 0.06 cfm/sqft as per ASHRAE standard or 10% of circulated air volume, whichever is the greater<br>• Return air to platform areas is extracted and either returned to the AHU's or exhausted as required<br>• Using of enthalpy sensors to determine benefits of using return air or outside air<br>• Mixture of outside and return air is cooled by a cooling coil<br>• Water-cooled chiller units with screw compressors are recommended to be provided and estimated capacity for a typical station would be around 750- 900 TR<br>• In view of the temperate outdoor conditions, alternatively, it is possible to utilize air cooled chiller units<br>• Considering outside temperature during winter season in Patna City, train heat is utilized for station heating hence only cooling unit installed |
| **FCU** | Main technical specifications are planned as follows<br>• FCU is exclusively for chilling<br>• Fresh air can be planned either with separate fresh air unit or with AHU for technical room<br>• Where fresh air is required it will be supplied to indoor unit via a fresh air supply system, complete with filter, common to a group of ancillary areas<br>• Return air grilles will be fitted with washable air filters for re-circulation of air<br>• Temperature of technical rooms are to be considered as 24°C±1°C with 50% RH and for non technical rooms design temperature may be considered as 25°C±1°C with 50% RH<br>• Temperature control will include an alarm setting, which is activated on attaining high temperature |

Source: DPR and JST

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 as follows.

**Table 12-12: Operating Modes for Tunnel Ventilation**

| Conditions | Contents |
|---|---|
| **Normal Conditions** | The normal condition is when the trains are operating to timetable.<br>During summer and the monsoon seasons, the vent shafts to the surface will enable the tunnel heat to be removed due to train movements. For less severe environmental conditions, the vent shafts will be open to atmosphere. 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 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.<br>During congested operations, TVS is operated to maintain a specific temperature in the vicinity of the car air conditioner condenser coils. 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. |
| **Emergency Conditions** | Emergency conditions are when smoke is generated in the tunnel or station trackway.<br>In emergency conditions, TVS 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. |

Source: DPR

Specifications of TVS Fans are assumed as follows.

**Table 12-13: Specifications of TVS Fans**

| Item | Specifications |
|---|---|
| **TVS Fans** | Main technical specifications are planned as follows<br>• Tunnel ventilation fans will be installed in each of fan rooms near vent shafts<br>• There shall be two fans in a fan room at each end of the station<br>• Fan capacity depends on inter-station distances and may vary from 60 cum/s to 100 cum/s<br>• Trackway exhaust system will have two fans of each 30 cum/s<br>• Connections to tunnels and shafts will be through damper units that may be either electrically or pneumatic actuated |

Source: DPR

Codes and Standards

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

SEDH – Subway Environment Design Handbook
ASHRAE – Handbook, current series
NFPA – 130, latest edition

### (2) Other Mechanical Equipment

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 the Tunnel Ventilation as well as Smoke Management system will normally be done through Operation Control Centre (OCC).

## 12.2 Reviews of Existing Studies and Proposals for Improvement

### 12.2.1 Power Supply Facilities

### (1) Power Receiving Facilities

Power for the extended and newly constructed line sections are supplied by extension from the existing equipment or new one from the electric power company.

- JST queried PMRCL about the status of power purchase agreement including Renewable Purchase Obligation (RPO). In response to JST's inquiry, PMRCL made a reply, "The Power purchase & contract demand agreement will be done with SBPDCL (State DISCOM) prior to final installation, testing & Commissioning of the RSS." (Power requirement for both RSS with source connectivity has already been communicated to STU i.e., BSPTCL and the licencee company SBPDCL.) In fact, it isn't at present, however they said any arrangement will be entered. The required power purchase will be done in mid of year 2024 if as planned.

  The RPO targets for FY 2021-22 as stipulated by BERC are as given below:

| | |
|---|---|
| RPO (%) | 17.00% |
| Solar (%) | 8.00% |
| Non-solar (%) | 9.00% |

Bihar has two big DISCOMs, NSPDCL and SBPDCL. According to BERC (2022), "*Tariff Order of DISCOMs (NBPDCL & SBPDCL) for FY 2022-23*" (p218), NBPDCL achieved 62.19% Solar and 114.67% Non-solar compliance and SBPDCL has achieved 59.34% Solar and 109.43% Non-solar compliance against the target for FY 2021-22. Bihar has not progressed in the use of solar power as a whole. Therefore the Commission directed to put forth more efforts to procure the balance solar energy required to meet the RPO requirements of FY 2021-22 and shortfall in FY 2019-20. The DISCOMs have submitted that they have already taken steps to enhance their Renewable Energy mix and SBPDCL could not only achieve the RPO targets, but also considerable surplus of Solar energy and Non-solar energy for FY 2022-23 to FY 2024-25.

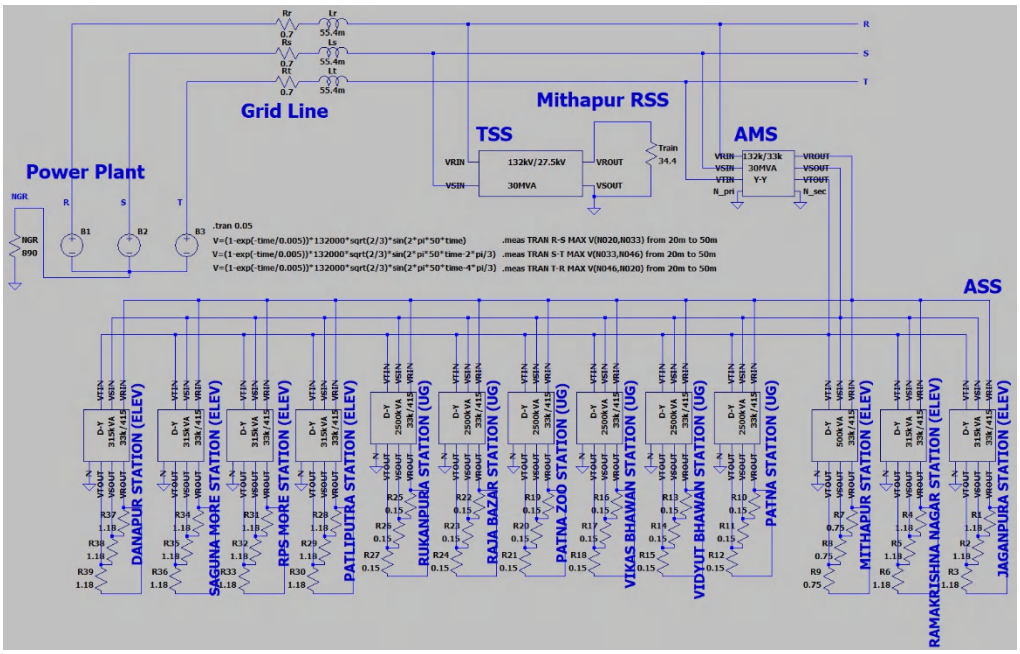
- Power transmission lines are installed between RSS and GSS to receive power from BSPTCL. According to PMRCL, EHV cable would be installed and maintained by PMRCL.
- It is necessary for the stable operation and passenger security to deliver the stable electric supply. Therefore to ensure redundancy is important for the system design. Mithapur RSS and New ISBT RSS are fed from GSS at 132kV voltage through 2 circuit, 3-phase cable lines respectively. Furthermore Each RSS has backup facilities and loads can receive parallel supply from two RSSs. In normal conditions, Mithapur RSS will feed corridor 1 and New ISBT RSS will feed Corridor 2. In case either of the two RSS fails, then the other RSS will feed both the corridors. Under normal conditions, the power supply from each RSS is shared, and all power shall be available from the other RSS in emergency conditions such as one RSS failure. For the above reason, JST evaluates that the measures of stable electric supply are sufficient.
- According to PMRCL, Gas-Insulated Switchgear (GIS) is used in RSS/TSS and at ASS of underground stations. GIS confines high-voltage components in a single gas tank. Even its cost is relatively high, it reduces the site space, ensures the safety of electric power workers and workers of manufacturers, and prevents power reception failure due to wildlife intervention.
- JST queried whether it is possible for the protective relay in TSS to protect all corridor areas while extended feeding in power failure. PMRCL made a reply, "Protective relays in TSS are capable to protect all areas of TSS."
- According to PMRCL, they are supposed to use Single-phase transformers in TSS. They have already ordered and the products are in testing stage. When Single-phase transformer instead of Scott-connected transformer is used, there is some possibility of causing any problem of unbalanced three-phase loads. Therefore JST suggested installing Scott-connected transformer. In response to JST's suggestion, PMRCL made a reply, "The voltage unbalancing will be taken care at Grid level as it is done in Delhi. Conditions in Patna are similar to Delhi. Moreover, Patna being a rapidly developing city is potentially cable of managing unbalancing at Grid Level only. Work has been already awarded for PE-01 (RSS contract) so any change at this stage is not possible."

The phase voltage unbalance rate is defined according to IEC61000-4-30, the threshold doesn't exist publicly. But when this unbalance becomes excessive, it can create problems for the lift and escalator, etc. in the station. Just for reference, the Approved Model Specifications of Japan recommend that electric supply systems using AC feeding system should be designed and operated to limit the maximum voltage unbalance to 3 percent.

If any problem caused by voltage unbalance occurs after the operation, it is necessary to take any countermeasure. Scott-connected transformer for traction is one of the solutions.

Numerical Simulation of Voltage Unbalance

JST investigated the effect of voltage unbalance on the low-voltage side of station's ASS when single phase transformer is used for traction. Each component was modeled according to DPR and simulated using LTSpice XVII (hereinafter referred to as SPICE). The systematic diagram modeled on Mithapur RSS is shown below.




Source: JST

**Figure 12-3: Systematic Diagram modeled on Mithapur RSS**

The back impedance $Z_L$ (Power Plant to Grid Line) is calculated using NEMA (National Electrical Manufacturers Association) Standard AB1, short-circuit capacity of power supply 1,000 MVA and X/R = 25. The short-circuit capacity at 132 kV is 1,000 MVA, and the reference capacity of the system is 10 MVA, in which case $\%Z_L$, $Z_L$ and the back inductance L are following.

$\%Z_L = 10\ \text{MVA} \div 1{,}000\ \text{MVA} = 1\%$

$Z_L = R_L + jX_L = (132\ \text{kV})^2 \div 10\ \text{MVA} \times 1\% = 17.42\ \Omega$

$Z_L = 0.696 + j17.41$ ($\because$ X/R = 25)

$L = 17.41\ \Omega \div 2\pi f = 17.41 \div (2\pi f \times 50) = 0.0554\ \text{H}$

Concerning Transformers, since an exciting current is sufficiently small compared to the load current, the exciting current loss is not simulated here. The distribution of leakage inductance on the primary and

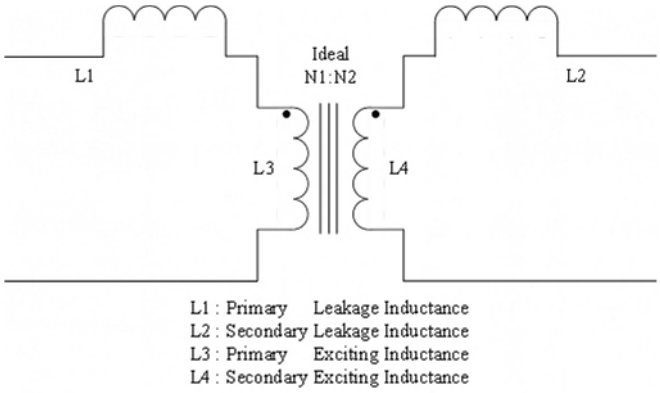
secondary sides is mostly the primary side, and the secondary side is set to 1 nH for convenience purpose. Although the inductive coupling factor k is generally said to be 0.99 or more, it is set to 1, the same as an ideal transformer, in order to facilitate the convergence of calculations. Rated capacity, Connection, Primary Voltage, Secondary Voltage and % impedance of transformers used in the simulation are in the table below.

**Table 12-14: Specifications of Transformer used in Simulation**

| | Rated Capacity (VA) | Connection | Primary Voltage (V) | Secondary Voltage (V) | %Z (Equipment base) | Remark |
|---|---|---|---|---|---|---|
| TSS | 30 M | Single Phase | 132k | 27.5 k | 13.8 % | Traction |
| AMS | 30 M | Y – Y | 132k | 33k | 12.5 % | Auxiliary |
| ASS | 315 k | D – Y | 33k | 415 | 7 % | ELEV |
| | 500 k | D – Y | 33k | 415 | 7 % | ELEV |
| | 2,500 k | D – Y | 33k | 415 | 7 % | UG |

Source: JST

As an example, we show how to derive the inductance of the transformer in AMS given the rated capacity, transformation ratio, and % impedance. The model of AMS's Transformer is shown below.




Source: JST

**Figure 12-4: Model of AMS's Transformer**

At first, to find the total impedance Z = R + jX. Since R is sufficiently small compared to X, only X is considered. The reactance component X = ωL for one phase is following.

$$X = (132\ \text{kV})^2 \div 30\ \text{MVA} \times 12.5\% = 72.6\ \Omega$$

The total leakage inductance on the primary and secondary sides is following.

$$L_{total} = 72.6\ \Omega \div 2\ \pi f = 72.6 \div (2\ \pi \times 50) = 0.231\ \text{H}$$

Since $L_2$ on the secondary side is 1 nH, the primary side $L_1$ is 0.231 H. For the inductive coupling factor k = 1, $L_4$ on the secondary side is arbitrarily set to 100 (a.u.). Considering the voltage ratio 132 kV/33 kV, the primary side $L_3$ is following

$$L_3 = L_4 \times (132\ \text{kV} \div 33\ \text{kV})^2 = 1{,}600\ \text{(a.u.)}$$

The inductance values to be input in SPICE are in the table below.

**Table 12-15: Inductance Values of AMS's Transformer**

| k = 1 | Primary | Secondary |
|---|---|---|
| Leakage Inductance | L1: 231 (mH) | L2: 1 (nH) |
| Exciting Inductance | L3: 1,600 (H) | L4: 100 (H) |

* Calculated the other transformers in the same way according to the connection.
Source:JST

The back impedance, traction load and auxiliary load are used as parameters for the simulation conditions. The loads are simulated by inserting a resistance between the lines in the secondary side of TSS and ASS. The traction load is set to 0 MVA for no single transformer's load, 14 MVA for normal maximum load and 22 MVA for emergency maximum load under the condition of traction system failure in New ISBT TSS. The Auxiliary load is set to 13.9 MVA with a demand factor of 0.8 for the total equipment capacity of ASS. In this condition, effective line voltages of the secondary side at Patna Station (UG) were obtained. According to IEC61000-4-30, Line voltage unbalance rate was calculated by the following formula.

$$Vub = \sqrt{\frac{1-\sqrt{3-6\beta}}{1+\sqrt{3-6\beta}}} \times 100$$

$$\beta = \frac{|V_{ab}|^4+|V_{bc}|^4+|V_{ca}|^4}{(|V_{ab}|^2+|V_{bc}|^2+|V_{ca}|^2)^2}$$

Simulation results are in the table below.

**Table 12-16: Simulation Results**

| No. | Short-Circuit Capacity (MVA) | Traction Load (MVA) | Auxiliary Load (MVA) | Line Voltage *V*ab (V) | Line Voltage *V*bc (V) | Line Voltage *V*ca (V) | Voltage Unbalance Rate *V*ub (%) |
|---|---|---|---|---|---|---|---|
| 1 | 1,000 | 0 | 13.9 | 399.0 | 399.1 | 398.8 | 0.05% |
| 2 | 700 | | | 398.0 | 398.1 | 397.8 | 0.05% |
| 3 | 400 | | | 395.4 | 395.4 | 395.1 | 0.05% |
| 4 | 1,000 | 14 | | 391.8 | 397.8 | 401.0 | 1.35% |
| 5 | 700 | | | 388.2 | 396.8 | 401.2 | 1.93% |
| 6 | 400 | | | 378.7 | 394.1 | 401.1 | 3.38% |
| 7 | 1,000 | 22 | | 388.0 | 397.8 | 402.3 | 2.12% |
| 8 | 700 | | | 382.7 | 396.8 | 402.9 | 3.03% |
| 9 | 400 | | | 368.8 | 394.1 | 403.2 | 5.26% |

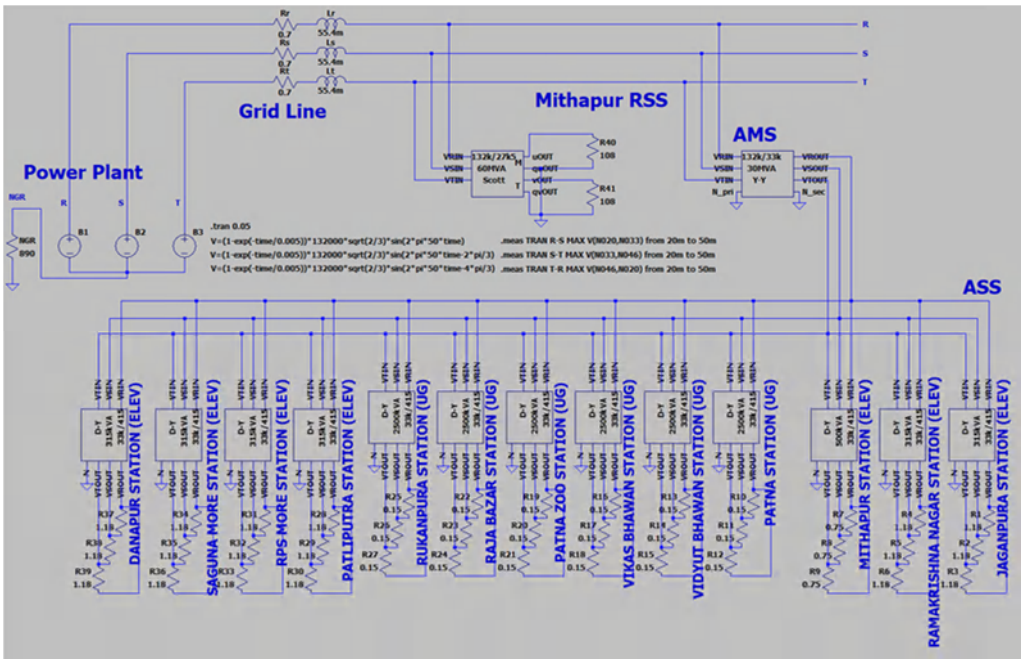
Source: JST

According to the simulation performed under the conditions assumed as Mithapur RSS, if the traction load was 0 MVA, the voltage unbalance rate on the secondary side wouldn't exceed 3 % even under the short-circuit capacity 400 MVA. Furthermore, It was found that the voltage unbalance rate would exceed 3 % when the short-circuit capacity of the power supply is below 400 MVA under normal traction maximum load (14 MVA) or below 700 MVA under emergency traction maximum load (22 MVA). That is, as the short-circuit capacity decreases or the traction load increases, the phase balance is lost and the voltage unbalance rate increases. Although we did not perform the simulation for New ISBT RSS this time, we can

expect similar results to the Mithapur RSS because of the similar facility configuration and demand forecast.

In a large city like Delhi, voltage unbalance may not be a problem as the short-circuit capacity of the power supply can be imagined sufficiently to be large. However, in Patna City, there is a concern that the short-circuit capacity of the power supply can decrease due to the long distance from the power plant, in other words, the length of the transmission line. Therefore, regarding this point, it is important to confirm with State Transmission Utility (STU) how much the actual short-circuit capacity and the actual back impedance at the power receiving point of RSS will be. After that, it is necessary to consider the voltage unbalance. As a result of consideration, Scott-connected transformer for traction is one of the solutions if any measure is required.

A Scott-connected transformer is consisted of a kind of circuit used to produce two-phase electric power from 3-phase source. And it can balance load between the phases of the source. The system diagram with the Scott-connected transformer modeled is shown below. The capacity of Scott-connected transformer is set to 60 MVA (30 MVA × 2 circuit). And two circuit loads of the secondary side is under a balanced condition.




Source: JST

**Figure 12-5: Systematic Diagram with Scott-Connected Transformer Modeled**

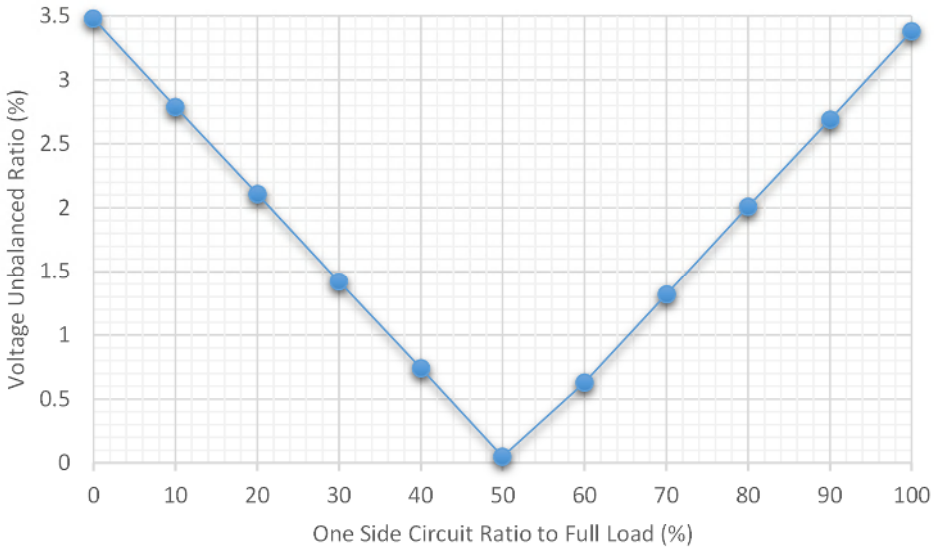
Using this circuit model, simulations were performed with the single phase transformer under the same condition that the voltage unbalance rate exceeded 3%. Simulation results are in the table below.

**Table 12-17: Simulation Results with Scott-Connected Transformer**

| No. | Short-Circuit Capacity (MVA) | Traction Load (MVA) | Auxiliary Load (MVA) | Voltage Unbalance Rate *Vub* (%) | Remark |
|---|---|---|---|---|---|
| 1 | 700 | 22 | 13.9 | 3.03% | Single Transformer (Ref) |
| 2 | | 11+11 | | 0.05% | Scott-Connected |
| 3 | 400 | 14 | | 3.38% | Single Transformer (Ref) |
| 4 | | 7+7 | | 0.05% | Scott-Connected |

Source: JST

In this results, we can figure out that Scott-connected transformer would suppress the voltage unbalance if two circuit loads of the secondary side is under the balanced condition. In other words, the voltage unbalance can be suppressed if power distribution to feeders of two ways can be evenly distributed. However, if two circuit loads are unbalanced, the voltage unbalance rate increases with the load ratio. The relation between the voltage unbalance and the load ratio at No.4 is shown below.




Source: JST

**Figure 12-6: Relation between Voltage Unbalance and Load Ratio**

As you can see from this graph, the more balance the load ratio, the better the voltage unbalance get depressed. Conversely, when one circuit has almost the load, the voltage unbalance rate approaches value of the single-phase transformer. That is, provided that a certain degree of load ratio is maintained, the Scott-connected transformer can effectively reduce the voltage unbalance rate.

### (2) Traction Power Facilities

- According to DPR, the high density traffic is supposed be like a peak period headway of 3.0 minutes for both corridors in the future. Considering the line length, estimated PHPDT and economic advantages offered by 25kV AC system, it is proposed to adopt 25kV AC system for Patna metro.

- When adopting AC feeding system we should concern about the emerging of the Electro Magnetic Interference (EMI). Because Booster Transformer is proposed for EMI mitigation JST queried whether Booster Transformer would be installed or not. In response to JST's inquiry, PMRCL made a reply, "The department of telecommunication has given clearance to charge the system without using Booster Transformer." Therefore it is possible to use the simple feeding system in all areas.
- According to PMRCL, return conductor will be connected to main earth terminal at every 500 m in elevated and underground section, similar to the practice being followed in DMRC. JST think that the earthed system is appropriate.
- JST queried about setting up sub sectioning posts in order to recover normal operation at in case of the feeder accident. In response to JST's inquiry, PMRCL made a reply, "There are 4 sub sectioning and paralleling post each in corridor 1 & corridor 2 to recover the normal operation, moreover, 2 sub sectioning post in corridor 1 & 3 in corridor 2 are provided for further smoothing of operation in case of faults." And the power supply in Depot is also redundant. For the above reason, JST think that the measures of stable electric supply are sufficient.
- JST queried whether any countermeasure such as mounting a backup battery to the train are considered when the train might stop at the way point between stations in case of all grid power outage. In response to JST's inquiry, PMRCL made a reply, "In their cases evacuation will be done as per the established procedure."
- JST queried about the distance (10 m) of each supporting point in the underground area. In response to JST's inquiry, PMRCL made a reply, "Maximum design speed of ROCS in the function of sag (corrugation) in Contact wire/ROCS, and as the contact is design and built, supporting distance will be decided as per the design of ROCS." According to PMRCL, the distance between two supports for most of the designs for a speed potential of 90 kmph is about 11 to 12 m under the rule in India. The distance of 10 m is same distance in Delhi metro, and they said that there is no problem with the equipment. Just for reference, the Approved Model Specifications of Japan recommend that the distance of each supporting point of ROCS should be designed to limit the maximum of 7 m considering with the sag of the contact wire.

### 12.2.2 Mechanical Facilities

- The Indian Standards & Codes, which pertain to office-buildings, commercial centers and other public utility buildings, have no guidelines on temperature standards to be maintained for the underground mass rapid transit systems as yet. But the performance requirements for ventilation facilities meet the standards established in India and are considered reasonable.

# 13. Depot

## 13.1 Track Layout

According to DPR, the rail depot is supposed to locate at the southeast of the New ISBT station adjacently and the double track of access line between the main line and the depot is proposed. The depot is supposed to stable and maintain all trains of Corridor 1 and Corridor 2.

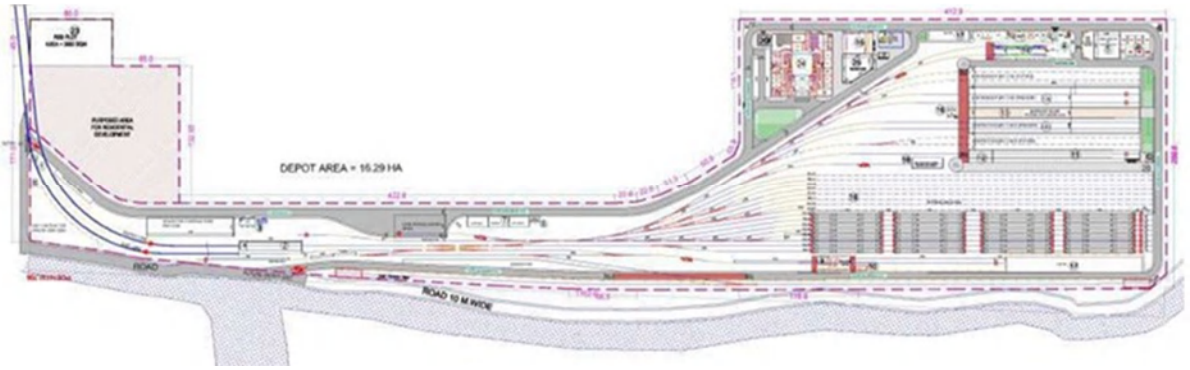
This section describes the issues on the current alignment of the depot as a result of reviewing.

The basic specifications of the depot are as follows.

**Table 13-1: NEW ISBT Depot Basic Specifications**

| Item | Spec |
|---|---|
| Area | 19.6ha |
| Stabling capacity | 64 trainsets (3 cars per trainset) |
| Number of storage tracks | 16 track (4 trainsets stabling per track) |
| Effective length of storage track | 331m |
| Number of inspection track | 5 track (Two of the tracks are planned for the future.) |
| Number of main workshop track | 4 track (Two of the tracks are planned for the future.) |
| Wheel lathe track | 1 track |
| Indoor cleaning track | 1 track |
| Test track | 1 track |
| Automatic train washing plant | 1 set |
| Loading / Unloading track | 1 track |
| Administration Office | 1 building |
| Crew Office | 1 building |

Source: PMRCL, JST




Source: DPR

**Figure 13-1: Current Layout Plan of New ISBT Depot**

## 13.2 Issues identified by alignment review

### 13.2.1 Number of trains stabling on storage tracks

The current depot layout has 16 storage tracks and one storage track can accommodate 4 trainsets of 3-cars train. Given this layout, it is readily anticipated that the trains parking at far end of storage track have difficulty to depart since only one side has the depot access track. In general, one storage track accommodates it up to two trainsets. Therefore, it is recommended to make a train diagram for the depot operation and check whether it would be possible to achieve the train operation without any problem even if one storage track accommodates four trainsets.

Additionally, according the latest depot layout plan, only half of storage tracks will be operational at the time of the inauguration and another half of tracks will be available at the time of the future expansion. For the purpose of smooth train operation, it is recommended to build all 16 storage tracks at the time of the inauguration to reduce the number of stabling train per track.

### 13.2.2 Location of the main workshop and the test track

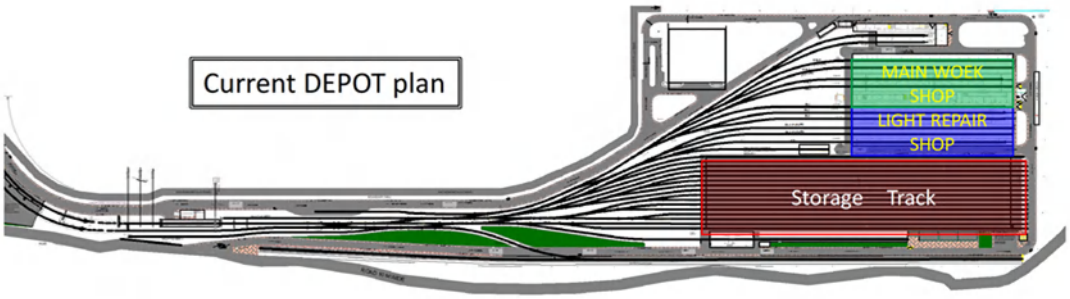
Since the main workshop and the test track are not adjacent to each other, trains need to cross the spur line from/to the depot to move to the test track after overhaul. Moreover, these trains are forced to switchback several times in a way to the test track due to the turnout layout.

Even the overhauled trains have the risk of getting stuck due to unexpected troubles. Therefore, the desirable alignment is to allow a train move smoothly from the main workshop and the test track. Given with the shape of the depot site, however, if the test track is located on the same side of the main workshop, it will be difficult to place some buildings on the current layout. In addition, the test run line is supposed to be fenced off from the surrounding area for safety reasons and there should be no railroad crossing. To achieve this, the test track would have to be located on the perimeter of the depot, otherwise the depot yard would be divided. Considering the current layout plan that has less impact on the surrounding area, the re-layout of test track is found difficult.

### 13.2.3 Proposal for improvement of depot

#### (1) Proposal for the depot alignment

As a result of study on the feasibility of re-layout of the overall facility layout, it is found that re-layout requires the significant change in the shape of depot site or the additional land. Therefore, it is concluded to follow the current plan of the basic facility layout in this study.

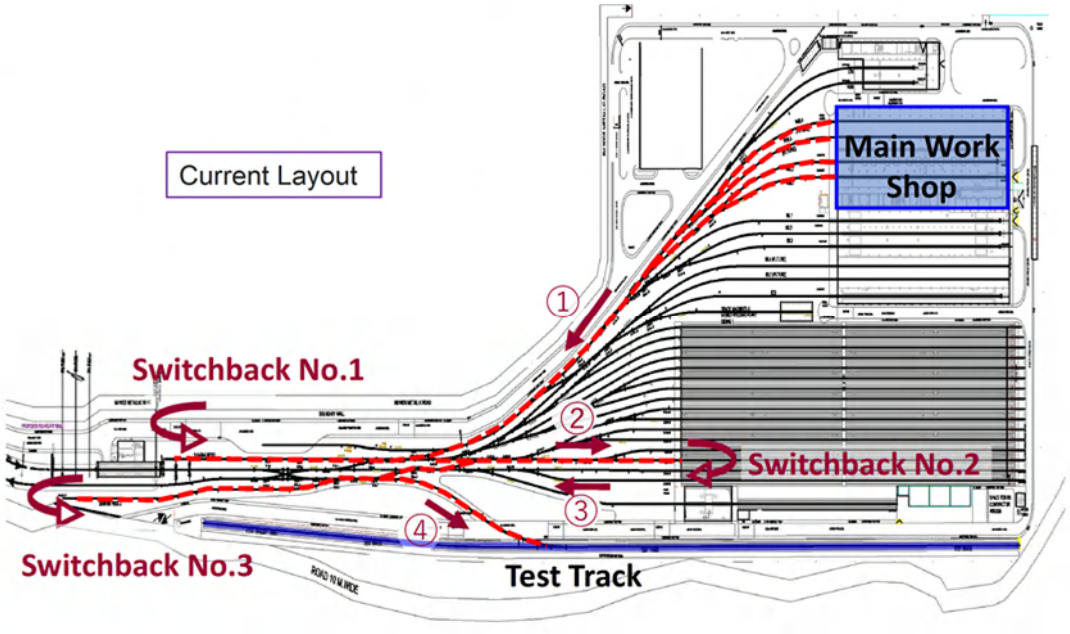



Source: DPR

**Figure 13-2: Location map of main facilities at New ISBT depot**

1) Route improvement between the main work shop and the test track

As mentioned, the current alignment plan cannot place the test track beside the main work shop, and therefore a train needs to turn back three times on the way. See "Figure 13-3" for the travel route between the Main Work shop and the test track in the current plan.



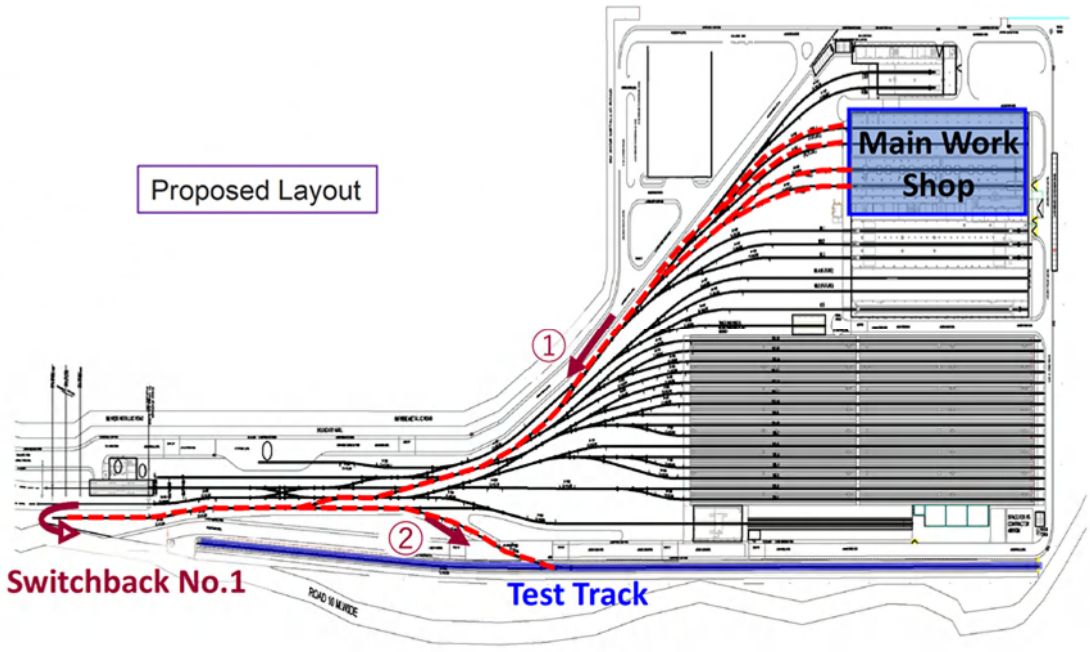

Source: DPR, JST

**Figure 13-3: Current route plan between depot and test track**

After assembling at the main workshop, trains move to the test track for the final operational testing. Troubles may be caused on the way before the operational testing is performed. Therefore, the route to the test track should be as short as possible to prevent such a risk from affecting the train dispatching from and returning to the depot. From this viewpoint, the frequent turn-back operation forced in the current plan has a high risk.

This study reviews the layout of turnouts and proposes the alignment modification that allow trains to move from the depot to the test track in the shortest route without turning back.

See "Figure 13-4" for the route of the test track train after the wiring change.




Source: DPR, JST

**Figure 13-4: Proposal for improvement of train route between main workshop and test track**

In this proposed alignment, the route from the main workshop to the depot is simplified so that only one switchback is enough. Although additional four turnouts are required for this modification, there is no change in the function of the depot in general.

Refer to Attachment 5 for depot plan after alignment change.

#### 2) Results of depot improvement proposals

The proposed improvements have been adopted by PMRCL and, at the time of this report's writing, work has begun on the DEPOT alignment changes.

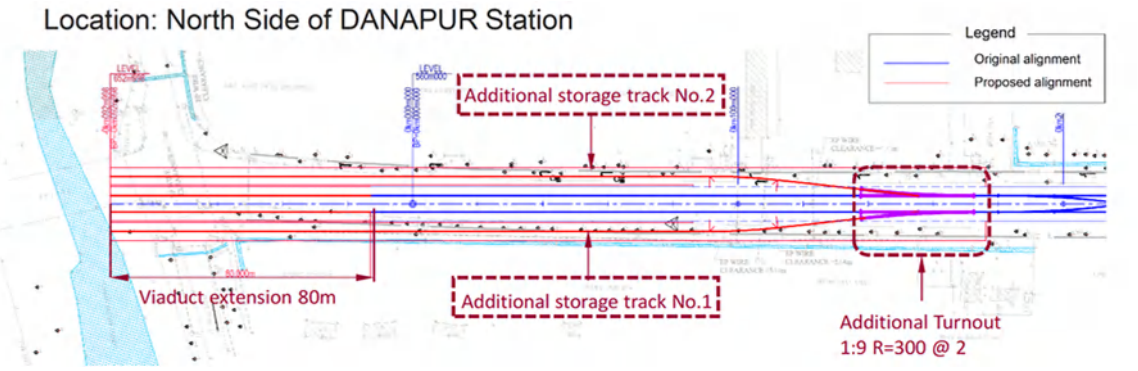
### (2) Proposal for storage track outside depot

#### 1) Addition of storage track to DANAPUR station

The current plan assumes that New ISBT depot accommodates all trains of Corridor 1 and Corridor 2. As seen in the layout of the Khemni Chak station where tracks of both corridors are linked, there is the branch of diamond crossing and out-of-service trains in Corridor 1 need to cross the main line to move to Corridor 2, and vice versa. This is not desirable since the diamond crossing causes blocking trains in Corridor 2 and affect the operation. It is difficult to completely avoid blocking by crossing, however the addition of storage track to Corridor 1 can lessen a number of trains crossing Corridor 2 by accommodating some trains.

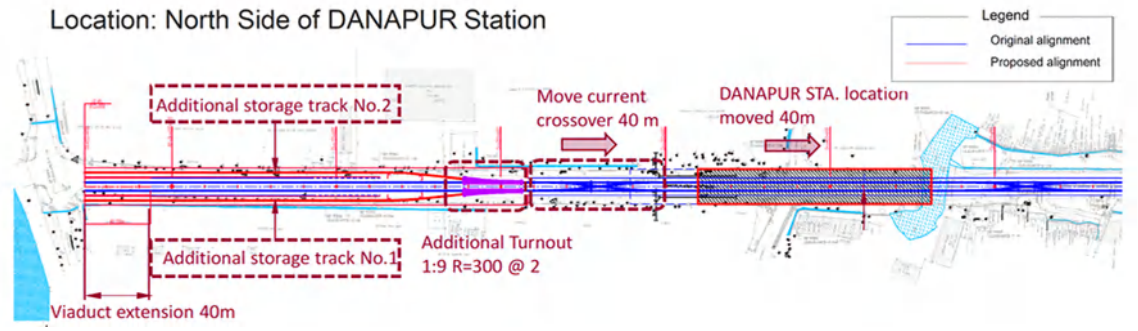
The recommended location for this additional storage track is near the terminus. Considering the operation to send the out-of-service trains in early morning and midnight, the location is preferably far from the New ISBT depot. From these reasons, the proposed location of this additional storage track is near Danapur Station, the starting point of Corridor 1.

Figure 13-5 and Figure 13-6 show the proposed layout.




Source: JST

**Figure 13-5: Additional storage track near DANAPUR station, Version 1**




Source: JST

**Figure 13-6: Additional storage track near DANAPUR station, Version 2**

To avoid the additional land acquisition and the impact on the current plan, the proposed layout of the additional storage track is at the lead track at the north side of Danapur Station. In detail, one storage track is to be placed on both sides of the double track of lead track, that is, two storage tracks are proposed in total.

There are two proposed layout as shown in Figure 13-5 and Figure 13-6.

The difference is the end point of the viaduct on the north side. In case of Version 1, the viaduct is extended as reached to the river and may interfere with the road bridge. To avoid this, Version 2 shifts the Danapur Station 40 m south and change the position of the northern end of the viaduct accordingly.

### 2) Decision about Proposal for Additional Storage Track

PMRCL decided not to add the storage track since the variation in the alignment design at the current stage is difficult. Moreover, they did not consider both the change in the station location and the north extension of the viaduct preferred.

## 13.3 Depot Planning

The following lines, buildings, and facilities are planned in the depot.

**Table 13-2: Lines, Buildings, and Facilities in Depot**

| | |
|---|---|
| **Indoor Lines** | Stabling Lines |
| | Inspection Lines |
| | Workshop Lines |
| | Pit Wheel Lathe |
| | Engineering Train Unit Workshop Cum Emergency Re-railing Shed |
| **Outdoor Lines** | Car Delivery Area |
| | Automatic Coach Washing Plant |
| | Test Track |
| | Heavy Cleaning Shed |
| **Building** | Train Operator Booking Office |
| | Administrative Building |
| | Watch Towers |
| **Facilities** | Power Supply |
| | Standby Power Supply |
| | Compressed Air Supply |
| | Water Supply, Sewerage and Drainage Works |
| **Machineries** | Plant and Machinery |
| **Others** | Parking Facilities |

Source: DPR

## 13.4 Workshop Facilities

The following plant and machinery are planned in the depot and workshop.

**Table 13-3: Plant and Machinery in Workshop**

| Category | Plant & Machinery | Quantity |
|---|---|---|
| Material Handling | Travelling over head EOT cranes for workshop 25/5T | 1 |
| | Travelling over head EOT cranes for inspection bay 1.5T | 1 |
| | Travelling over head EOT cranes for ETU shed 5T | 1 |
| | Jib crane for workshop 3T | 1 |
| | Synchronised pit jacks system for car lifting | 2 set |
| | Car body stands for keeping 6 car shells | 12 |
| | Dummy bogies | 6 |
| | Mobile lifting jacks 15T | 2 |
| | Mobile lifting jacks 10T | 2 |
| | Battery powered locomotive | 2 |
| | OHE Inspection Car | 2 |
| | Road mobile crane 5T | 1 |
| | Fork lift truck 3T | 2 |
| | Fork lift truck 2T | 2 |
| | Pallet truck | 4 |
| | TATA truck | 1 |
| | Scissors type lifting trolley 2T | 2 |
| | Hydraulic trolleys 2T | 2 |
| Wheel Shop | 500T wheel press | 1 |
| | Vertical boring m/c (Turret Lathe) | 1 |
| | Multipurpose wheel lathe | 1 |
| | Axle turning lathe | 1 |
| | Axle UST inspection machine | 2 |
| | Radial drill m/c | 1 |
| | Induction heater | 2 |
| | Bearing extractor | 2 |
| Bogie Shop | Bogie wash/cleaning plant | 1 |
| | Bogie static load testing m/c | 1 |
| | Shock absorber testing m/c | 1 |
| | Spring scragging & testing m/c | 1 |
| | Magnacheck crack detector | 1 |
| | Glowcheck crack detector | 1 |
| Rotating m/cs | Baking oven | 1 |
| | Dynamic balancing | 1 |
| | Traction motor test console | 1 |
| | Motor compressor test bench | 1 |
| | Tan delta testing instrument | 1 |

| Category | Plant & Machinery | Quantity |
|---|---|---|
| Other m/cs | Under floor pit wheel lathe | 1 |
| | Chip crusher and conveyor for pit wheel lathe | 1 |
| | Automatic washing plant for metro cars | 1 |
| | High-pressure washing pump for front/rear end cleaning of cars | 1 |
| | Turntable for one car | 1 |
| | Turntable for bogies | 4 |
| | Driving cab simulator | 1 |
| | Water de-mineralization plant | 2 |
| | Painting booth for separate parts | 1 |
| | Floor cleaning machine | 4 |
| | Welding equipment | 5 |
| | Compressor 500 cfm | 1 |
| | DG set 320 kVA | 3 |
| | Battery charger | 2 |
| Machine Shop | Guillotine sharing m/c | 1 |
| | Sheering, punching & cropping | 1 |
| | Universal tool cutter & grinder | 1 |
| | Vertical surface grinder | 1 |
| | Centre lathe 2m bed | 1 |
| | Centre lathe 1m bed | 1 |
| | Radial drill m/c | 1 |
| Test Benches /Instrument | Brake test bench | 2 |
| | SPM test bench | 2 |
| | Door test bench | 2 |
| | Inverter test bench | 1 |
| | Other test benches (MCB, PMPU, etc.) | 1 |
| | Oscilloscope | 1 |
| Furniture /Material Storage /Small Tools | Vertical storage system for DCOS store | 1 |
| | Computer MMIS with LAN connectivity | 1 |
| | Storage racks | LS |
| | Industrial furniture | LS |
| | Electric and pneumatic tools | LS |
| | Measuring and testing equipment | LS |
| | Tool kits | LS |
| | Mobile safety steps | 10 |

Source: DPR

# 14. Environmental Impact Assessment (EIA)

## 14.1 Outline of the project component

The Project components are shown in the table below.

**Table 14-1: Project Component**

| Category | Facilities to be included in the Project |
|---|---|
| Civil | Construction of viaducts, railway tracks<br>Construction of underground stations<br>Construction of Depot |
| Building | Construction of elevated stations<br>Construction of Depot |
| Supply system | Receiving substations, Transformer etc. |
| Other relevant facilities | Quarry and borrow pit<br>Construction yard etc. |

Source: JST

## 14.2 Condition of Natural Environment

### 14.2.1 Land use

The target area for Corridor 1, 2 and Depot begins from the Danapur cantonment to the Depot area through some commercial areas, residential areas, special areas and public areas. The underground section is from the western area of Patliputra St. to the northern area of Mithapur St. for Corridor 1, and from Patna St. to the northern area of Malahi Pakri Sr. for Corridor 2. The other section is elevated, and Patna St. and Khemni Chak St. are allocated as an interchange station between corridor 1 and corridor 2




Source: JST based on Patna Master Plan 2031

**Figure 14-1: Land Use Condition along Patna Metro**

**Table 14-2: Environmental Condition along Patna Metro**

| Corridor 1 | |
|---|---|
|  |  |
| 1. Danapur | 2. Saguna More |
|   |  |
| 3. RPS More | 4. Patliputra |
|  |  |
| Under Digha AIIMS Elevated Rd. | 5. Rukanpura |
|  |  |
| 6. Raja Bazar | 7. Patna Zoo |

| **Corridor 1** | |
|---|---|
|  |  |
| 8. Vikas Bhawan | 9. Vidyut Bhawan |
|  |  |
| 10. Patna | 11. Mithapur |
|  |  |
| 12. Ramkrishna Nagar | 13. Jaganpura |

| **Corridor 2** | |
|---|---|
|  |  |
| Railway Patna Station | 2. Akashvani |

| **Corridor 2** | |
|---|---|
|  |  |
| 3. Gandhi Maidan | 4. PMCH |
|  |  |
| 5. University | Between University St. and Stadium St. |
|  |  |
| 6. Moin-ul-Haq-Stadium | 7. Rajendra Nagar |
|  |  |
| Railway Rajendra Nagar Station | 8. Malahi Pakri |

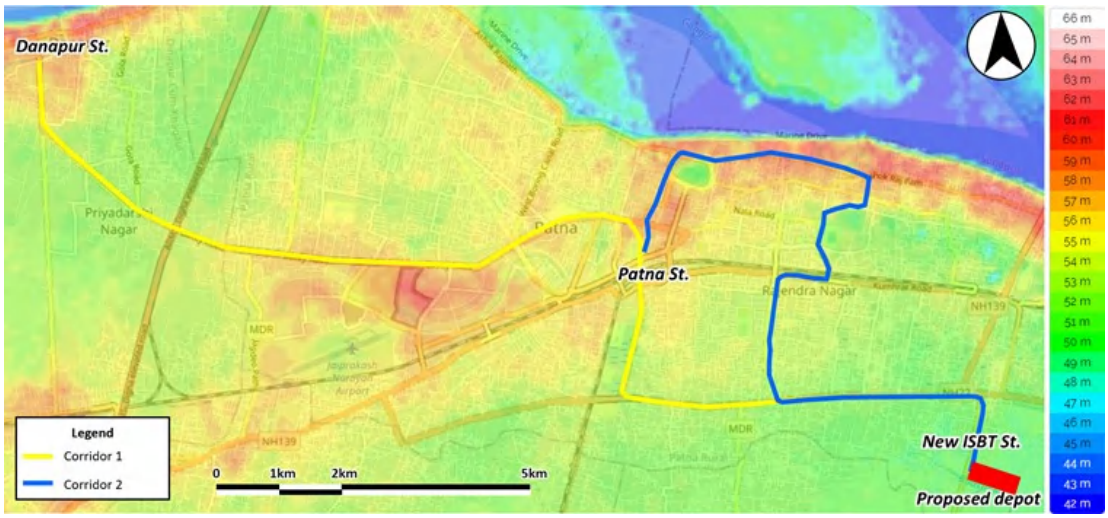
| Corridor 2 | |
|---|---|
|  |  |
| 9. Khemni Chak | 10. Bhootnath |
|  |  |
| 11. Zero Mile | 12. New ISBT |

| Proposed Depot area | |
|---|---|
|  |  |

Source: JST

### 14.2.2 Geology and Topography

The target area for Corridor-1, 2 and Depot is located from latitude 25°34’13" N to 25°37’59"N and from longitude 85°02’ 27" to 85°11’57" E. The corridors are planned to cross the center of Patna city. The altitude of the proposed Depot area is the lowest, but it is over 50 m. The highest altitude is recorded at the middle point of Corridor-1 and Corridor-2 along the Ganges River with an altitude of 60 m.

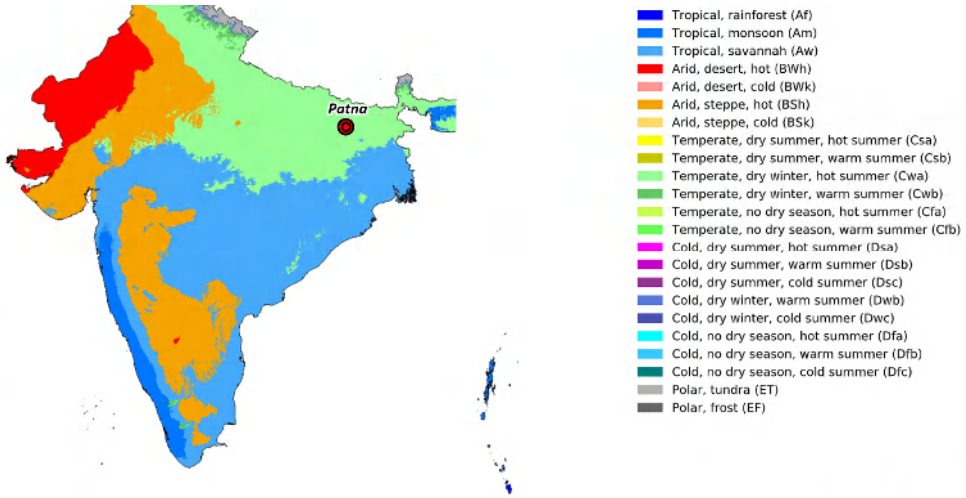



Source: JST based on topographic-map.com

**Figure 14-2: Land Use Condition along Patna Metro**

### 14.2.3 Climate

India is classified into 23 Köppen climate classifications in total because of the large nation land. The climate at Patna is divided into 3 seasons: the intense heat season from late March to early June, the rainy season from late June to late September, and the dry season from November to February. Patna, in which the construction site is located, belongs to the Monsoon-influenced humid subtropical climate and the temperature difference is large with 15℃ between the intense heat season and the dry season. The maximum temperature also ranges from 23℃ in January to 38.4℃ in May, and the average yearly rainfall in Patna is 1,213 mm.



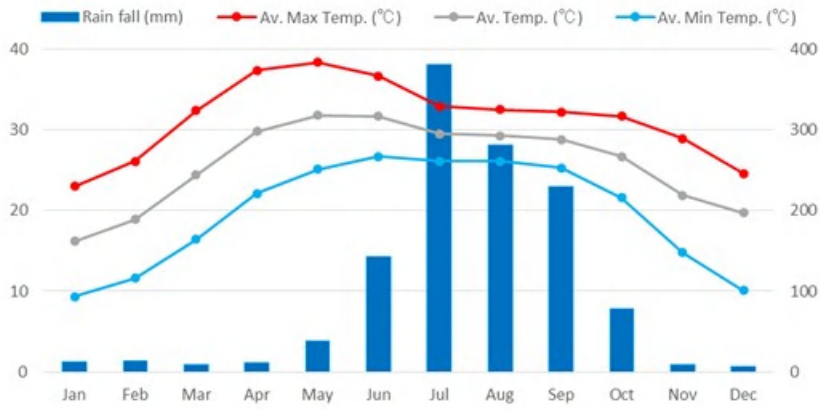

Source: Peel, M. C., Finlayson, B. L., and McMahon, T. A. (2007) (University of Melbourne)

**Figure 14-3: Köppen Climate Classification for India**

**Table 14-3: Weather Condition in Patna**

| Station | Item | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Patna | Rainfall | 12.2 | 14.1 | 9.4 | 10.8 | 38.1 | 142.5 | 381.0 | 281.6 | 229.3 | 78.6 | 8.7 | 7.0 | 1213.3 |
| | Temperature | 16.2 | 18.9 | 24.4 | 29.8 | 31.8 | 31.7 | 29.5 | 29.3 | 28.8 | 26.7 | 21.9 | 19.7 | 25.7 |
| | Max. Temp | 23.0 | 26.1 | 32.4 | 37.4 | 38.4 | 36.7 | 32.9 | 32.5 | 32.2 | 31.7 | 28.9 | 24.6 | - |
| | Min. Temp | 9.3 | 11.6 | 16.4 | 22.1 | 25.1 | 26.7 | 26.1 | 26.1 | 25.3 | 21.6 | 14.8 | 10.1 | - |

Source: JST based on the data of the India Meteorological Department




Source: JST based on the data of India Meteorological Department

**Figure 14-4: Weather Condition in Patna**

### 14.2.4 Natural Disasters

"PATNA MASTER PLAN 2031[36]" shows that Patna has a high risk for natural disasters because of a vulnerable city for earthquakes and floods due to Monsoon.

#### (1) Flood

Since Patna has lower average altitude than the flood level of the Ganges River except for the old town area on the northeast side of the project site, muddy currents flow into the city beyond the flood level of the river during the monsoon season, which causes damage. In 1975 and 1984, the flood levels were observed at 51.34 m and 51.6 m respectively. The left figure below shows the flood damage area in August 2016, and it can be seen that Patna has also been damaged in addition to the Saran and Vaishali districts on the north side of the River. However, according to the interview with PMRCL staff and some local people, JST has received their answer that there has been no flood damage in the project area. Google Earth also has a satellite photo (black and white) of August 2016 just after the flood, but the vehicles on the road along the alignment of Patna Metro can be checked. Additionally, according to the site inspection, waterstop boards shall be installed along the riverbanks to prevent floodwater from flowing into the city when the risk of flooding increases. From the above, it can be understood that the areas along the Patna Metro were not flooded. PMRCL is planning construction in a manner that adopts the results of safer predictions of flooding effects. For example, the planned elevation of the Depot is 50.3 m with a 3 m high embankment from the

[36] PATNA MASTER PLAN 2031, Town and Country Planning Organization Urban Development & Housing Department Patna, Bihar, 2016

existing ground level, which is higher than the High Flood Level of 48.7 m based on the 100-year flood.



Source: Mapping cropland impact from flooding in Saran & Vaishali (Bihar) using Theos1 Satellite Images (28 August 2016)

**Figure 14-5: Flood Damage Area in August 2016**

### (2) Earthquake

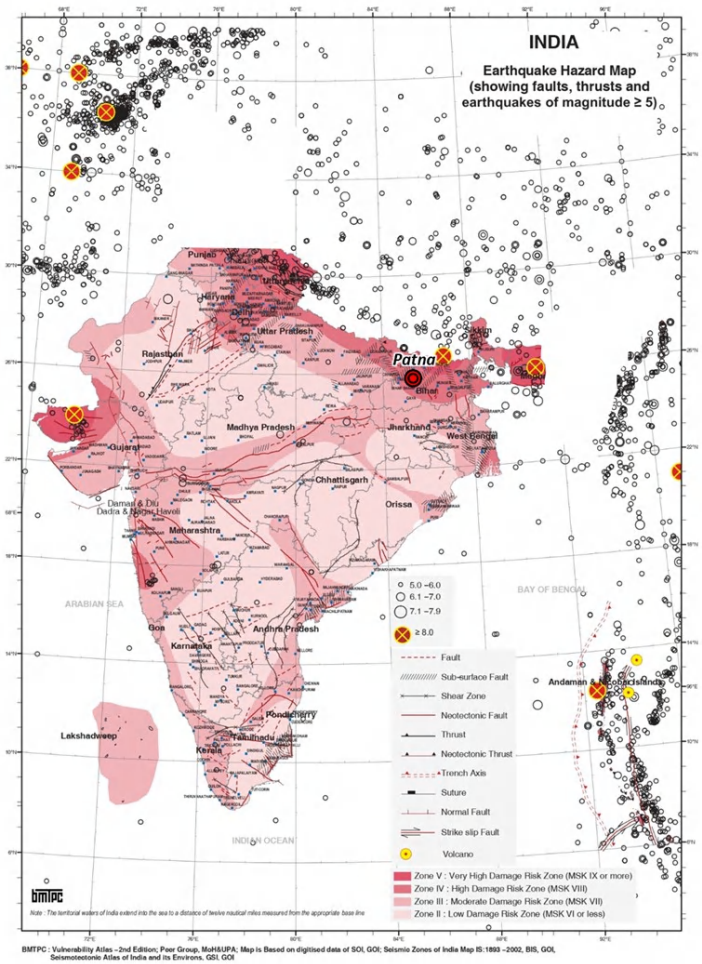
According to the seismic distribution map issued by the Bureau of Indian Standards, the project site is covered by Zone IV which corresponds with a high-risk area. The figure below explains the earthquakes with over magnitude 5 occurred in India and its surrounding areas for the 110 years from 1893 to 2002. Although there is a few number of occurred earthquakes in Patna, an earthquake with a magnitude of more than 8 has occurred at the point of 200 km northeast of Patna. According to PMRCL, there has been no large-scale earthquake damage in the project area. The damages caused by major earthquakes that occurred in recent years around Bihar state are shown below. Regarding the cause of deaths in both earthquakes, most of them were not directly caused by building collapses, but from heart attacks, panic, and riots after the earthquakes. Therefore, it can be said that there has been no earthquake damage in Patna city at least for the last 130 years.

**Table 14-4: Weather Condition in Patna**

| Year | Hypocentre | Magnitude | Number of death in Patna | Remarks |
|---|---|---|---|---|
| **1988** | South of Sagarmatha Zone, Nepal | 6.8 | 0 | There were no casualties or injuries in Patna, but several buildings collapsed and breakwaters were damaged[37]. |
| **2015** | Gandaki zone, Nepal | 7.8 | Unknown (Very few) | The number of casualties in Bihar state is 58 people, mainly close to the boundary with Nepal. Patna city is unknown), but most of them were not directly caused by building collapses, but from heart attacks, panic, and riots after the earthquakes[38]. |

Source: JST based on the data of India Meteorological Department

[37] https://reliefweb.int/map/india/india-severe-floods-bihar-state-august-2016-comparison-between-pre-and-post-flood-0
[38] https://zeenews.india.com/news/india/quake-toll-in-india-now- 78_1587267.html




Source: Building Materials and Technology Promotion Council

**Figure 14-6: Epicenter of Earthquakes with over M 5.0 in and around India**

## 14.3 Legal System Regarding Environmental Considerations in India

### 14.3.1 Laws and Regulations Regarding Environmental Considerations in India

#### (1) Environmental policy, strategies and legal frameworks

The law on the environment, the "Environment (Protection) Act 1986" has been enacted in India, which established the basic outline of environmental protection. The "National Environment policy" was established in May 2006, and the "Environment Impact Assessment Notification" 2006" on project categories for an environmental compliance certificate, screening and scoping procedures, public consultations, etc. has been enacted in September 2006. These procedures are under the responsibility of the Impact Assessment Division under the Ministry of Environment, Forest and Climate Change (hereinafter referred to as "MoEFCC").

## (2) Environmental Management Law

### 1) Environment (Protection) Act 1986

The Environment (Protection) Act is positioned as the Basic Environment Law in India, explains the basic outline of environmental protection, and consists of 4 chapters and 26 items in total. The law stipulates the central government's responsibilities for the prevention, management and reduction of environmental pollution. The government is empowered to develop appropriate rules to achieve the goals of the Act. The Act defines "Environment" as "includes water, air and land and the inter- relationship which exists among and between water, air and land, and human beings, other living creatures, plants, micro-organism and property". The Act provides the authority to prevent, regulate and reduce environmental pollution and activities which damage environment. The government is empowered to set rules in sectors where environmental protection and regulation are required.

### 2) Environment Impact Assessment Notification" 2006

EIA in India is positioned as the primary procedure for reviewing and approving new or modified projects under the National environment policy 2006, which was developed under the Environmental (Protection) Act. The EIA procedure is stipulated in the Environmental Impact Assessment Notification 2006, which includes Requirements of prior Environmental Clearance (hereinafter referred to as "EC"), Assessment authority, Categorization of projects and activities, Screening, Scoping and Appraisal Committees, EC application, Validity of EC, Post EC Monitoring, and Transferability of EC etc. Various formats have also been established in the Notification. There is no EIA ordinance system by regional governments in India. The environmental categories of India are divided into three groups, A, B1 and B2 as shown in the table below. The criteria between category A and B is relatively clear, but the criteria between category B1 and B2 is indefinite. Therefore, it will be judged by screening process. The EC issuance supervisory authority, the inspection authority, and other necessary documents are different for each category.

**Table 14-5: Supervisory authority, Inspection authority for each category in India**

| Category | Supervisory authority (Regulator) | Inspection authority | EIA | EC | Monitoring |
|---|---|---|---|---|---|
| A | MoEFCC | EAC | Need | Need | Need |
| B1 | SEIAA | SEAC | Need | Need | Need |
| B2 except Mining, extraction of natural resources | SEIAA | SEAC | Needless | Need from SEIAA | Need |
| B2 for Mining, extraction of natural resources | DEIAA | DEAC | Needless | Need from SEIAA | Need |
| Non-EC project | - | - | Needless | Needless | Need |

* SEIAA: State/Union Territory Environment Impact Assessment Authority, SEAC: State or Union territory level Expert Appraisal Committee, DEIAA: District Environment Impact Assessment Authority, DEAC: District Expert Appraisal Committee

Source: Environment Impact Assessment Notification 2006

### (3) Environmental Screening for the Project

#### 1) Screening Based on the Environmental Impact Assessment Notification 2006

EC is not required because all railway projects in India are exempt from EC procedures.

#### 2) Screening Based on the JICA Guidelines

The project is classified as "Category A" in the JICA guidelines published in April 2010, because it corresponds with the condition that it is likely to have significant adverse impacts on the environment and society as a railway sector which has a characteristic of large-scale involuntary resettlement.

### (4) Survey policy of the project

This project is not applicable for the EC procedure in India mentioned in the EIA Notification 2006, and is classified as Category A in the JICA guidelines. Therefore, the survey shall be conducted in accordance with the JICA guidelines. In the table below, the corresponding part of each item mentioned in the Notification is listed for reference.

**Table 14-6: Gap between EIA Procedure in India and JICA guidelines**

| Subject | JICA guidelines | EIA in India (EIA Notification 2006) | Policy of this survey |
|---|---|---|---|
| Underlying Principles | • Environmental impacts that may be caused by projects must be assessed and examined in the earliest possible planning stage. Alternatives or mitigation measures to avoid or minimize adverse impacts must be examined and incorporated into the project plan. | Details of Alternatives shall be examined, and EMP would consist of all mitigation measures for each item. | Follow JICA guidelines (PMRCL has prepared an EIA report when planning for this project began in 2020. This feasibility study will conduct an additional EIA survey to examine alternatives and mitigation measures in line with the JICA Guidelines. PMRCL will be requested to incorporate the results of this survey in the project plan.) |
| Information Disclosure | • EIA reports (which may be referred to differently in different systems) must be written in the official language or in a language widely used in the country in which the project is to be implemented. When explaining projects to local residents, written materials must be provided in a language and form understandable to them<br>• EIA reports are required to be made available to the local residents of the country in which the project is to be implemented. The EIA reports are required to be available at all times for perusal by project stakeholders such as local residents and copying must be permitted | MOEF&CC shall display the Summary of the draft EIA report on its website, and also make the full draft EIA available for reference at a notified place during normal office hours at the Ministry in Delhi. | Follow JICA guidelines (In 2020, PMRCL has already prepared an EIA report in English and Hindi, which is widely used in India. PMRCL has explained the project to local residents through public consultations when preparing the EIA. PMRCL will be requested to make the report's copy available to local stakeholders throughout the project.) |

| Subject | JICA guidelines | EIA in India (EIA Notification 2006) | Policy of this survey |
|---|---|---|---|
| Stakeholder meeting | • For projects with a potentially large environmental impact, sufficient consultations with local stakeholders, such as local residents, must be conducted via disclosure of information at an early stage, at which time alternatives for project plans may be examined. The outcome of such consultations must be incorporated into the contents of project plans.<br>• In preparing EIA reports, consultations with stakeholders, such as local residents, must take place after sufficient information has been disclosed. Records of such consultations must be prepared<br>• Consultations with relevant stakeholders, such as local residents, should take place if necessary throughout the preparation and implementation stages of a project. Holding consultations is highly desirable, especially when the items to be considered in the EIA are being selected, and when the draft report is being prepared. | Public consultation shall be conducted after submission of draft report. | Follow JICA guidelines<br>(Meetings were held by PMRCL when preparing EIA Report and SIA Report, and JST checked the minutes of these meetings and confirmed its compliance with the JICA Guidelines.) |
| Assessment Items | • The impacts to be assessed with regard to environmental and social considerations include impacts on human health and safety, as well as on the natural environment, that are transmitted through air, water, soil, waste, accidents, water usage, climate change, ecosystems, fauna and flora, including trans-boundary or global scale impacts. These also include social impacts, including migration of population and involuntary resettlement, local economy such as employment and livelihood, utilization of land and local resources, social institutions such as social capital and local decision-making institutions, existing social infrastructures and services, vulnerable social groups such as poor and indigenous peoples, equality of benefits and losses and equality in the development process, gender, children's rights, cultural heritage, local conflicts of interest, infectious diseases such as HIV/AIDS, and working conditions including occupational safety.<br>• In addition to the direct and immediate impacts of projects, their derivative, secondary, and cumulative impacts as well as the impacts of projects that are indivisible from the project are also to be examined and assessed to a reasonable extent. It is also desirable that the impacts that can occur at any time throughout the project cycle should be considered throughout the life cycle of the project. | In addition to the direct and immediate impacts of projects, their derivative, secondary, and cumulative impacts as well as the impacts of projects that are indivisible from the project are also to be examined and assessed to a reasonable extent. | Follow JICA guidelines<br>(Where there are impacts stated in the JICA Guidelines that were not sufficiently analysed in the EIA report prepared by PMRCL, this survey will conduct additional assessments, Environmental impact assessments for facilities related to this project, such as quarry, borrow pits, and construction yards, will be conducted to the extent possible.) |

| Subject | JICA guidelines | EIA in India (EIA Notification 2006) | Policy of this survey |
|---|---|---|---|
| Monitoring, Grievance Redress Mechanism | • Project proponents etc. should make efforts to make the results of the monitoring process available to local project stakeholders.<br>• When third parties point out, in concrete terms, that environmental and social considerations are not being fully undertaken, forums for discussion and examination of countermeasures are established based on sufficient information disclosure, including stakeholders' participation in relevant projects. Project proponents etc. should make efforts to reach an agreement on procedures to be adopted with a view to resolving problems. | Project proponents are required to submit environmental management plan & programme. It shall be mandatory for the project management to submit every half a year compliance reports in respect to the stipulated prior environmental clearance terms and conditions. | Follow JICA guidelines<br>(Request PMRCL to disclose monitoring results to the stakeholders, and to conduct additional meetings as needed throughout the project.) |
| Ecosystem and Biota | Projects must not involve significant conversion or significant degradation of critical natural habitats and critical forests. | Separately discussed in each constriction, law, and standard. | Follow JICA guidelines<br>(JST will conduct an assessment of critical natural habitats and critical forests, and will examine alternatives and mitigation measures. PMRCL will be requested to reflect the results in the project plan.) |
| Indigenous Peoples | Any adverse impacts that a project may have on indigenous peoples are to be avoided when feasible by exploring all viable alternatives. When, after such an examination, avoidance is proved unfeasible, effective measures must be taken to minimize impacts and to compensate indigenous peoples for their losses. | Separately discussed in each constriction, law, and standard. | No indigenous or ethnic minority communities were found in the area along the 2 corridors of the Project. |

Source: JST

### (5) Other environment-related permits required for this project

As mentioned above, the project is not applicable to the EC procedures in India, but various regional permits for Bihar state and Patna City shall be required as follows. The application period for the permits is mainly at the stage of pre-construction, construction, and operation. Regarding the permits for the section under construction, the table below shows the status of being approved and applied for the permits. C&D waste management plan approval as per the C&D waste management rule 2016, is required if the quantity of waste generated is more than 20 ton per day or 300 ton per month. At the present, the quantity generated from the all sections is below the limit. Hence it is not required at the current stage. The concerned contractor should acquire the approval when it exceeds the limit.

**Table 14-7: Environment-related Permits**

| No. | Item | Acts/ Rules | Concerned Agency | Stage |
|---|---|---|---|---|
| 1 | Consent to Establish and Consent to Operate for Batching plant | The Water (Prevention and Control of Pollution) Act, 1974, amended 1988 and The Air (Prevention and Control of Pollution) Act 1981, amended 1987 | Bihar State Pollution Control Board | Pre-Construction |
| 2 | Permission for felling trees | Tree Preservation Act | Forest Department/ Municipal Authorities | Pre-construction |
| 3 | Construction and Demolition (C &D) Waste Management Plan | C&D Waste Management Rules, 2016 | Local Authority | Pre-construction |
| 4 | Permission for extraction of ground water | Environment (Protection) Act, 1986 | CGWA (Local Unit) | Pre-construction as well as for operation |
| 5 | Generation, handling, storage and transportation of hazardous waste | Hazardous and Other wastes (Management & Transboundary Movement) Rules, 2016 | Bihar State Pollution Control Board | Construction and Operation |
| 6 | Consent to establish and operate Sewage Treatment Plant (STP) and Effluent Treatment Plant (ETP) | The Water (Prevention and Control of Pollution) Act, 1974, amended 1988 | Bihar State Pollution Control Board | Operation |

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Table 14-8: Permit status for the sections under construction as of Nov 2022**

| No. | Item | PC-01 From Malahi Pakri to New ISBT | PC-02 New ISBT Depot | PC-03 From Akashvani to Malahi Pakri | PC-04 From Danapur to Patliputra, and from Mithapur to Jaganpura |
|---|---|---|---|---|---|
| 1 | Consent to Establish and Consent to Operate for Batching plant | Approved | Not yet submitted | Applied | Approved |
| 2 | Permission for felling trees | Approved | | Approved | Approved |
| 3 | Construction and Demolition (C &D) Waste Management Plan | Not required | | Not required | Not required |
| 4 | Permission for extraction of ground water | Approved | | Approved | Approved |
| 5 | Generation, handling, storage and transportation of hazardous waste | Approved | | Applied | Applied |
| 6 | Consent to establish and operate Sewage Treatment Plant (STP) and Effluent Treatment Plant (ETP) | To be submitted at the pre-operation phase | | | |

Source: PMRCL

## (6) Other environment-related Acts, regulations

Other environment-related Acts, regulations are shown as below.

**Table 14-9: Other environment-related Acts, Regulations**

| Category | Law, Act, Guideline |
|---|---|
| Air quality | Air (Prevention and Control of Pollution) Act, 1981<br>Air (Prevention and Control of Pollution) Rules, 1982<br>Revised National Ambient Air Quality Standards, Notification, 2009 |
| Water quality | Water (Prevention and Control of Pollution) Act, 1974<br>Water (Prevention and Control of Pollution) Rules, 1975<br>IS 10500 : 2012 Indian Standard DRINKING WATER — SPECIFICATION |
| Waste | Bio-Medical Waste (Management and Handling) Rules, 1998, as amended to date, 2003<br>The Batteries (Management and Handling) Rules, 2011 |
| Noise | Noise Pollution (Regulation and Control) Rules, 2000<br>EPA-1986, Noise pollution (Regulation Control), Rule-2000, PCLS/02/1992, IV$^{th}$ Edition. |
| Ecosystem | Wildlife Protection Act, 1972<br>The Wild Life (Protection) Amendment Act, 2002<br>The wild life (Protection) Rules, 1995<br>Biological Diversity Act, 2002<br>Indian forest Act,1927<br>Forest conservation act, 1980, 1988, etc.<br>National forest policy, 1988<br>Forest rights act, 2006<br>Forest conservation amendment rules, 2003 |
| Cultural and historical heritage | Ancient Monuments and Archaeological Sites and Remains (Amendment and Validation) Act, 2010 |

Source: JST

## 14.4 Comparative study of alternatives (Including No project)

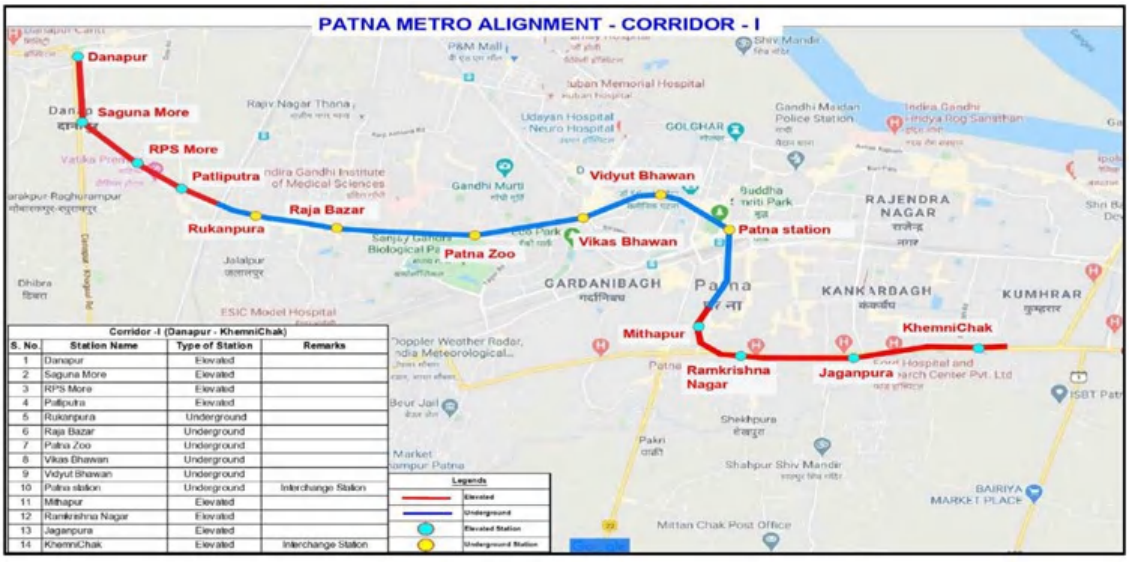
Alternatives for Corridor 1 and Corridor 2 are studied in the Updated Detailed Project Report (DPR) and the Social Impact Assessment (SIA) report. The JST analysed the following items in the comparative study of alternative plans.

- Possibility to start projects earlier.
- Reduction of the project cost
- Impact of the project on the surrounding environment
- Contribution to the reduction of road traffic congestion compared with zero option (without project).

### 14.4.1 Corridor-1

#### (1) Overview

Corridor 1 is planned as an elevated section between Danapur and Patliputra stations, starting from Danapur at the western end. There is a transitional section from an elevated section to an underground section towards the end of the line from Patliputra station, and an underground section starts from the east of Patliputra station. The line then reverts back to an elevated section between Patna and Mithapur stations and joins Corridor 2 at Khemni Chak station.




Source: DPR

**Figure 14-7: Route Overview of Corridor-1**

## (2) Alternatives

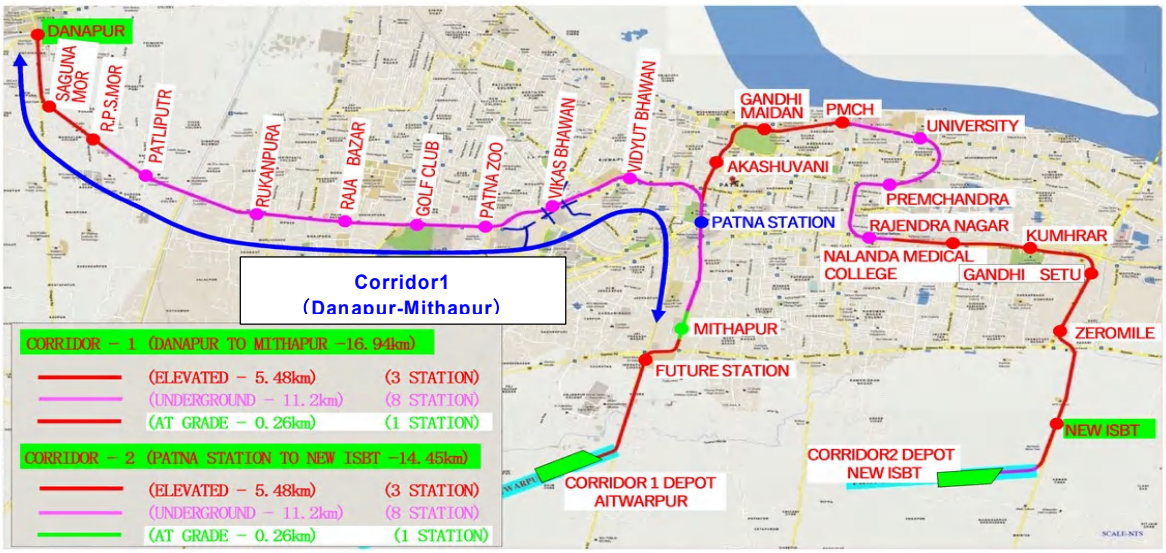
The following three alternatives are being considered including a case where the project is not implemented.

### 1) Alternative 1

Alternative 1 is the case where project is not implemented.

### 2) Alternative 2

Alternative 2 consists of 16.9 km route and 12 stations. Proposed line passes through Saguna More, Rukanpura, Raja Bazar, Zoo, Patna Station and Mithapur districts. This plan envisages the construction of a depot at Aitwarpur.

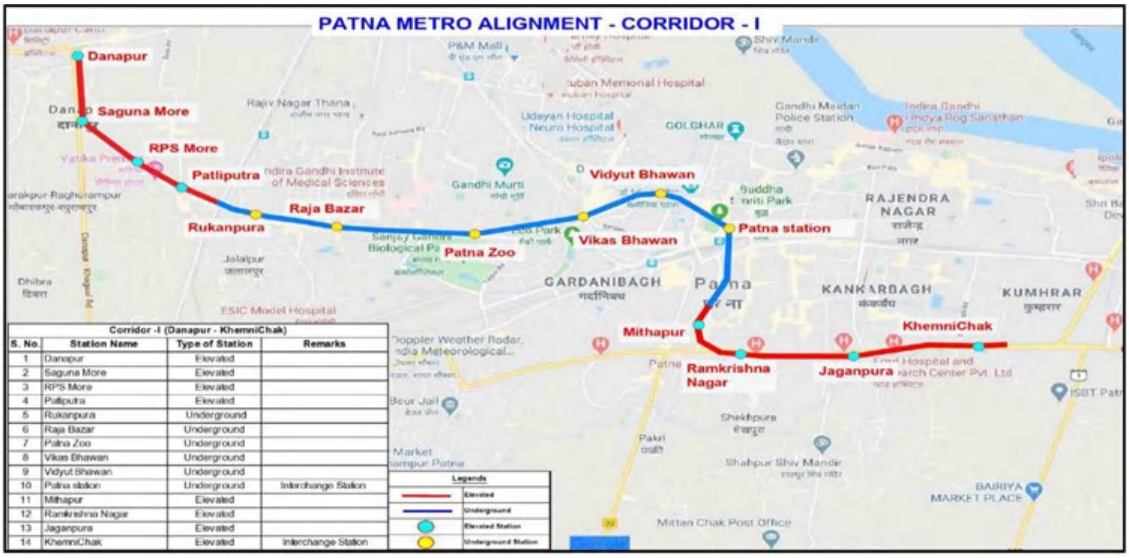



Source: DPR2018

**Figure 14-8: Route Overview of Alternative 2**

### 3) Alternative 3

Alternative 3 considers the Danapur - Khemni Chak section passing through Saguna More, Rukanpura, Zoo, Patna Station, Mithapur, Jaganpura and Khemni Chak. Unlike Alternative 2, this alternative proposed to connect Corridor 1 and Corridor 2 at Khemni Chak. The dedicated depot for Corridor 1 is not considered in this alternative and it is assumed that a depot near the New ISBT station is shared for Corridor 1 and Corridor 2 instead.




Source: DPR

**Figure 14-9: Route Overview of Alternative 3**

## (3) Results of the comparative study of alternatives

The table below shows the results of the alternatives evaluation with the 5 ratings set from +2 to -2 including Zero. A comparative evaluation shall be adopted, and it assigns +1 or +2 to the more desirable one and -1 or -2 to the less desirable one after comparing the three alternatives. Regarding the weighting of each evaluation item, since there are 10 items for environmental and social items, and it is more significant to focus on business sustainability, the item of Profitability and Cost, which are cost-effectiveness indicators, shall be evaluated with a double rate compared with the other environmental and social items. The total score was calculated for each alternative. As a result of the overall evaluation, the alternative 3 is assessed as the most suitable plan.

**Table 14-10: Comparative Study Results of Alternatives**

| No. | Comparative study item | Alternative 1. (Case in which the project is not implemented) | Alternative 2 | Alternative 3. (Adoption proposal) |
|---|---|---|---|---|
| 1 | Beginning point of route | - | Danapur | Danapur |
| 2 | End point of route | - | Mithapur | Khemni Chak |
| 3 | Length of route | - | 16.94 km<br>The spur track from/to the depot is long. Given that this track is used by a train out of service only, a not-for-profit section is longer. | 17.933 km<br>Although the route length is longer than Alternative 2, the section used for the revenue train is longer than it. Therefore, the revenue increase can be expected. |
| 4 | Route | - | Suguna - Danapur Main Rd<br>Bailey Rd<br>Fraser Rd<br>Mithapur Bus Stand Rd<br>Patna - Sitamarhi Rd<br>Patna - Gaya Rd | Suguna - Danapur Main Rd<br>Bailey Rd<br>Fraser Rd<br>Mithapur Bus Stand Rd<br>Patna - Sitamarhi Rd |
| 5 | Number of stations | - | 12 Stations<br>Comparing to the Alt.3, the available space for the railway is narrow along the route. | 14 Stations<br>Comparing to the Alt.2, the additional stations for the route altered improves the conveniences of passengers along the route. |
| 6 | Length of elevated section | - | 5.48 km | 7.393 km |
| 7 | Number of elevated stations | - | 3 Stations | 8 Stations |
| 8 | Length of underground section | - | 11.20 km | 10.54 km |
| 9 | Number of underground stations | - | 8 Stations<br>Comparing to the Alt.3, a larger number of underground stations worsens the road congestion during the construction period and increases the project cost. | 6 Stations<br>Comparing to the Alt.2, a smaller number of underground stations can avoid the road congestion during the construction period and reduces the project cost. |
| 10 | Length of at-grade section | - | 0.26 km | 0km |
| 11 | Ground level station | - | 1 Station | - |
| 12 | Number of depots | - | 1 Location<br>Due to long spur line between the main line and the depot, the increase of the project cost for the viaduct construction and the increase of energy consumption rate by out-of-service trains are anticipated. | Given the depot shared with Corridor 2, the depot dedicated for Corridor 1 is not needed. It has the advantages in the feasibility of the project by reducing the land acquisition and the procurement of facilities and equipment. |

| No. | Comparative study item | Alternative 1. (Case in which the project is not implemented) | Alternative 2 | Alternative 3. (Adoption proposal) |
|---|---|---|---|---|
| **Environmental and social considerations** | | | | |
| 13 | Air Quality | Further deterioration by increased traffic volume is expected. | Improvement of the situation is expected due to reduced traffic volume. | Improvement of the situation is expected due to reduced traffic volume. |
| | Rating | -1 | +2 | +2 |
| 14 | Noise and vibration | The increase of noise and vibration from the traffic and the car horns is expected. | The noise and vibration during/after the construction can be reduced by the preventive countermeasures. | The noise and vibration during/after the construction can be reduced by the preventive countermeasures. |
| | Rating | -1 | +1 | +1 |
| 15 | Earthquake/Flooding・Submergence | - | Although there is a risk of earthquake, flooding and submergence, the damage can be prevented by a countermeasures such as seismic retrofitting and the entrance/exit level raising. | Although there is a risk of earthquake, flooding and submergence, the damage can be prevented by a countermeasures such as seismic retrofitting and the entrance/exit level raising. |
| | Rating | 0 | 0 | 0 |
| 16 | Number of affected trees | - | 935 trees | 864 trees |
| | Rating | 0 | -2 | -2 |
| 17 | Affected landmark | - | - | - |
| | Rating | 0 | 0 | 0 |
| 18 | Land acquisition area<br>(However, the temporary construction area and the depot are excluded.)<br>Breakdown of land by owner<br>(However, the temporary construction area and the depot are excluded.) | - | 9.98 ha<br>*In addition, Alt.2 needs 14.40ha of another land acquisition for the depot connected to Corridor 1. A total of 24.39ha needs to be acquired.<br>Central Government Land: 0.10 ha<br>State Government Land: 3.30 ha<br>Private Land: 6.58 ha | 10.83 ha<br>*Alt.3 has no depot connected to Corridor 1.<br>Central Government Land: 3.79 ha<br>State Government Land: 2.05 ha<br>Private Land: 4.99 ha |
| | Rating | 0 | -2 | -1 |
| 19 | PAPs and PAFs<br>(The number includes PAFs not subjected to the resettlement.) | - | 1,178 persons (178 families)<br>*This number is from Corridor 1 and the depot. | 256 persons (52 families) |
| | Rating | 0 | -2 | -1 |
| 20 | Affected structures | - | 88 structures | 19 structures |
| | Rating | 0 | -2 | -1 |
| 21 | Traffic safety | Low | High | High |
| | Rating | -2 | +2 | +2 |
| 22 | Climate change | Increase in $CO_2$ emission is expected due to higher traffic volume. | Decrease in $CO_2$ emission is expected due to lower traffic volume. However, it incurs $CO_2$ emission from the electricity generation to operate the metro. | Decrease in $CO_2$ emission is expected due to lower traffic volume. However, it incurs $CO_2$ emission from the electricity generation to operate the metro. |
| | Rating | -2 | +1 | +1 |

| No. | Comparative study item | Alternative 1. (Case in which the project is not implemented) | Alternative 2 | Alternative 3. (Adoption proposal) |
|---|---|---|---|---|
| **Profitability** | | | | |
| 23 | Total Passenger area and Profitability | No passenger area | 9.4 $km^2$<br>(12 stations, assuming catchment area as a 500m radius)<br>The transfer station to the Corridor 2 is one (Patna Station).<br>941 thousand per day in 2031.<br>(the difference demand projection methodology with the Alt. 3 is unclear)<br>Number of transferring station: 1<br>2024 585,023 pax/day<br>2031 941,935 pax/day<br>2041 1,065,218 pax/day<br>2051 1,316,282 pax/day | 11.0 $km^2$<br>Three stations (Ramkrishna Nagar-Khemni Chak) increased but one station (Golf club) omitted, i.e., two stations increased. Simply 17% increase of profitability.<br>The transfer station to the Corridor 2 is two (Patna St and Khemni Chak), which will increase the network redundancy and accessibility.<br>978 thousand per day in 2031.<br>(the difference demand projection methodology with the Alt. 2 is unclear)<br>Number of transferring station: 2<br>This will increase network redundancy and passengers' accessibility twice from Alt. 2.<br>2024 598,998 pax/day<br>2031 978,052 pax/day<br>2041 1,144,930 pax/day<br>2051 1,444,632 pax/day |
| | Rating | 0 | +2 | +4 |
| **Cost** | | | | |
| 25 | Project cost | — | 6565.27 Rs. in Crore<br>The route length including the spur track from/to depot is shorter than Alt. 3, which means the maintenance cost will be lower than Alt.3. Given with a larger number of underground stations proposed, however, the project cost for the railway construction is expected to be higher than Alt. 3. | 5348.88 Rs. in Crore<br>The route length including the spur track from/to depot is longer than Alt.2 which means the maintenance cost will be higher than Alt.2. Given with a smaller number of underground stations proposed, however, the project cost for the railway construction is expected to be lower than Alt. 2. |
| | Rating | 0 | -4 | -2 |
| **Evaluation** | | -6 | -4 | +3 |
| | | 3rd | 2nd | 1st |

Source: DPR, PMRCL, Social Impact Assessment 2020, DMRC, JST

## (4) Sensitive Analysis

To assess the suitability of the weighting of the indicators for Environmental and social considerations, and cost-effectiveness, a sensitivity analysis was conducted as shown in the table below. As a result, it was confirmed that any change in the weighting of the relevant indicators would not affect the selection of the preferred alternative.

**Table 14-11: Sensitivity analysis result for the indicators of cost-effectiveness**

| Weighting for Indicators of environmental items compared to cost-effectiveness items | Ranking (Evaluation point) | | |
|---|---|---|---|
| | Alternative 1 | Alternative 2 | Alternative 3 |
| Half (0.5) | 2nd (-3) | 2nd (-3) | 1st (+2.5) |
| Same (1.0) | 3rd (-6) | 2nd (-4) | 1st (+3) |
| Double (2.0) | 3rd (-12) | 2nd (-6) | 1st (+4) |
| Triple (3.0) | 3rd (-18) | 2nd (-8) | 1st (+5) |
| **Weighting for Indicators of cost-effectiveness compared to environmental items** | **Alternative 1** | **Alternative 2** | **Alternative 3** |
| Half (0.5) | 3rd (-6) | 2nd (-2.5) | 1st (+1.5) |
| Same (1.0) | 3rd (-6) | 2nd (-3) | 1st (+2) |
| Double (2.0) | 3rd (-6) | 2nd (-4) | 1st (+3) |
| Triple (3.0) | 3rd (-6) | 2nd (-5) | 1st (+4) |

Source: JST

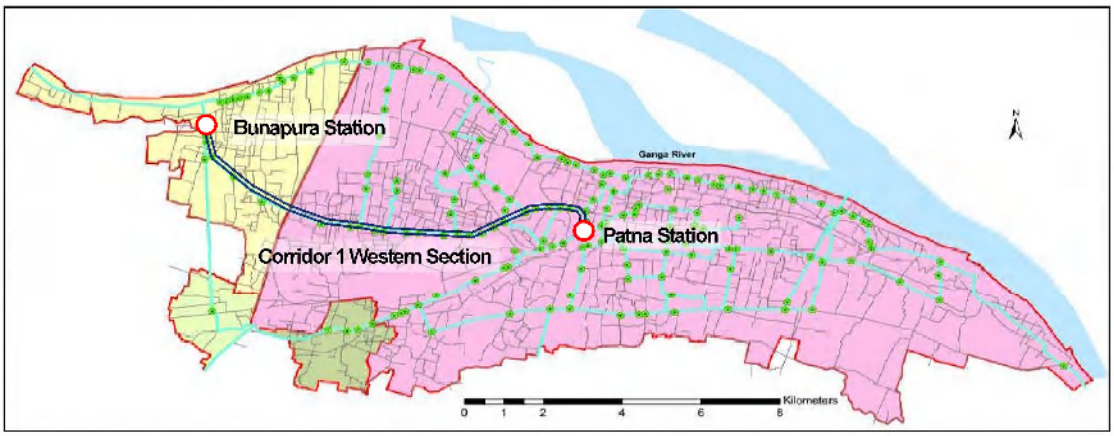
### (5) Validation of route selection

#### 1) West side selection (Danapur – Patna St.)

The same section of the route has been selected for both Alternatives 2 and 3. There are no parallel arterial roads other than Bailly Road along the project route. For the western side of the Patna city area, the existing bus routes are also distant from the project route except for Bailly Road, and there are no competing or alternative bus routes. The area around Bailly Road, where the western section of Corridor 1 will be introduced, is undergoing redevelopment as a residential area by a private company, and it is expected that demand from the surrounding residents will increase in the future. Currently an arterial road on the west side of the Patna city area where public transport such as buses are concentrated, this is deemed to be highly demanded for the introduction of rail-based transport. As a result of review, it is concluded that the proposed route is appropriate.

Reasons for selection of alternatives.

- To alleviate the traffic congestion compared with zero option (without project) by passengers transferred from main arterial roads and bus routes for which no alternative routes exist.
- To improve the convenience for residents living along the route.
- To reduce the project cost




Source: DPR2018

**Figure 14-10: Existing Bus Route**

2) South Side Selection (Patna – Mithapur, Khemni Chak)

Alternatives 2 and 3 of Corridor 1 have the same route to Mithapur station, the next station after Patna station. In the case of Alternative 2, Mithapur station would be the temporary terminus and the route would follow the Patna - Gaya Rd to the south and reach to future station envisaged at a point approximately 900 m from Mithapur station. The line continues further south to a planned depot approximately 3 km from Mithapur station. The depot in Alternative 2 is planned as a regular maintenance and overhaul facility. As Corridor 1 is not connected to Corridor 2, not only vehicles can be accommodated but also all maintenance can be completed at this depot. Under Alternative 2, if the route terminates at Mithapur station, the distance to the depot would be approximately 4 km, which is a very long distance for non-revenue services. The construction of non-revenue line is not desirable for the commercial feasibility since it increases the project cost and the electricity cost consumed by non-revenue train operation. In the case of Alternative 3, the route would follow Patna - Sitamarhi Rd to the east after Mithapur Station and it reaches to Khemni Chak Station, the junction station with Corridor 2, via Ramakrishna Nagar and Jaganpura station. The distance from Mithapur Station is 3.3 km, which is slightly shorter than the distance between Mithapur Station and the depot in Alternative 2. In reality, however, it is necessary to take into account the lead track, therefore, the track length would be almost the same. Alternative 3 does not required the depot used exclusively for Corridor 1 since its function is substitutionally handled by Corridor 2 depot. This can reduce the project cost and the impact on the surrounding area by land acquisition.

Reasons for selection of alternatives

- Improved profitability through the improvement of the convenience for residents along the rail line and an increase in the number of stations attracting more passenger.
- Reduction in the number of depots and its related spur line to lower the overall project cost and further reduce the land acquisition area.




Source: DPR2018,PMRCL,JST

**Figure 14-11: Comparative Figure for the Southern Section of Corridor-1**

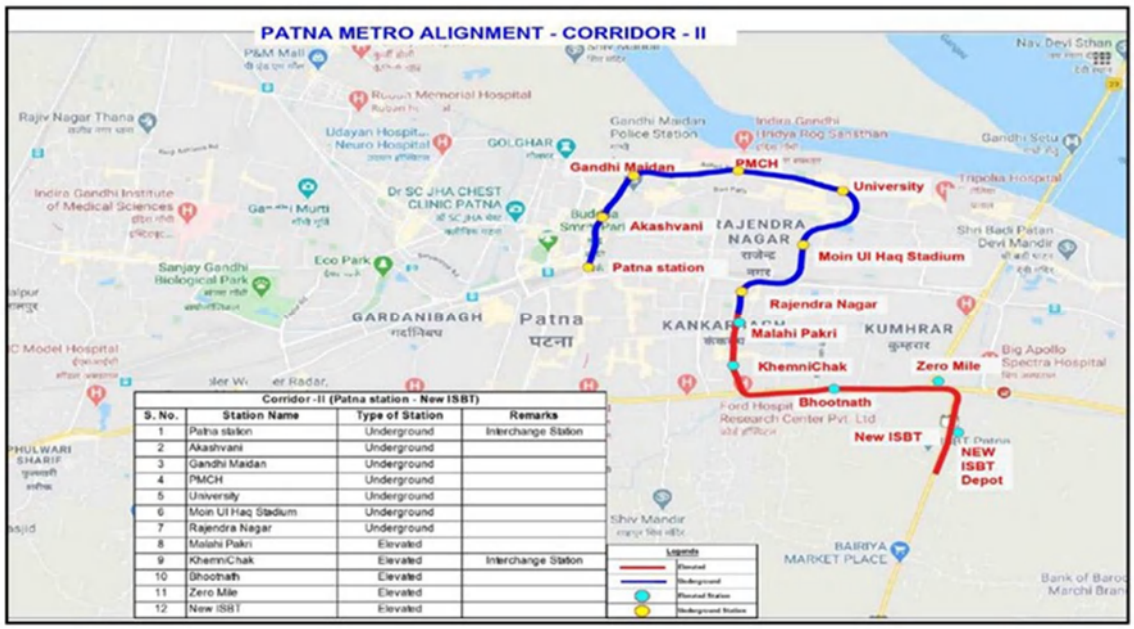
### (6) The conclusion from the comparison of alternatives

As a result of the validation of Alternative 2 and Alternative 3, the introduction of rail transport on Bailly Road is a desirable route from the perspective of transferring passengers from buses and reducing road congestion compared with zero option (without project) since Bally Road has no alternative bus route despite it is a major arterial road in the western section of the project route. Considering the long non-revenue section and the depot construction for the south section, Alternative 2 has the obvious disadvantages in terms of the increase of project cost and land acquisition. Although the Alternative 3 has almost same route length, it is more reasonable since the additional three stations can stimulate passenger demand for the railway. Given that the depot can be shared with Corridor 1 and Corridor 2, the reduction of the land acquisition and the depot construction cost can be expected even though the ordinary expenses by reducing the number of depots will be higher. Therefore, Alternative 3 has a high advantage. In terms of environmental and social considerations, the number of trees to be cut under Alternative 3 is 864, which is 71 less than Alternative 2, and the number of PAHs, PAFs, and affected structures are significantly reduced compared to Alternative 2, therefore Alternative 3 is highly advantageous overall.

## 14.4.2 Corridor-2

### (1) Overview

Corridor 2 is planned as an underground section between Patna and Rajendra Nagar stations, starting at Patna station. After Rajendra Nagar station, the transition to the viaduct starts at about 300m behind Malahi Pakri station and then the elevated section continues to the southward. The spur line to the depot is branched at the south of the terminal station, New ISBT station. Corridor 2 has the junction with Corridor 1 at Patna and Khemni Chak stations and the depot is shared with Corridor 1.




Source: DPR

**Figure 14-12: Overview of Corridor-2 route**

### (2) Alternatives

The following three alternatives are being considered as alternatives, including cases where the project is not implemented.

#### 1) Alternative 1

Cases where projects are not implemented

#### 2) Alternative 2

The route is planned as an elevated section from Patna Railway Station along Frazer road through Dak - Banglow Chowk, Akashvani, Gandhi Maidan and PMCH districts. The transition from the viaduct to the underground starts at PMCH station towards the east and Dinkar Chowk and Rajendra Nager stations are underground sections. A ramp is planned from Rajendra Nagar station towards the end of the line, where the line will again be elevated near Railway Coach Maintenance and will run via Gandhi Setu, Zero mile and Bodhgaya road to the terminus at ISBT.

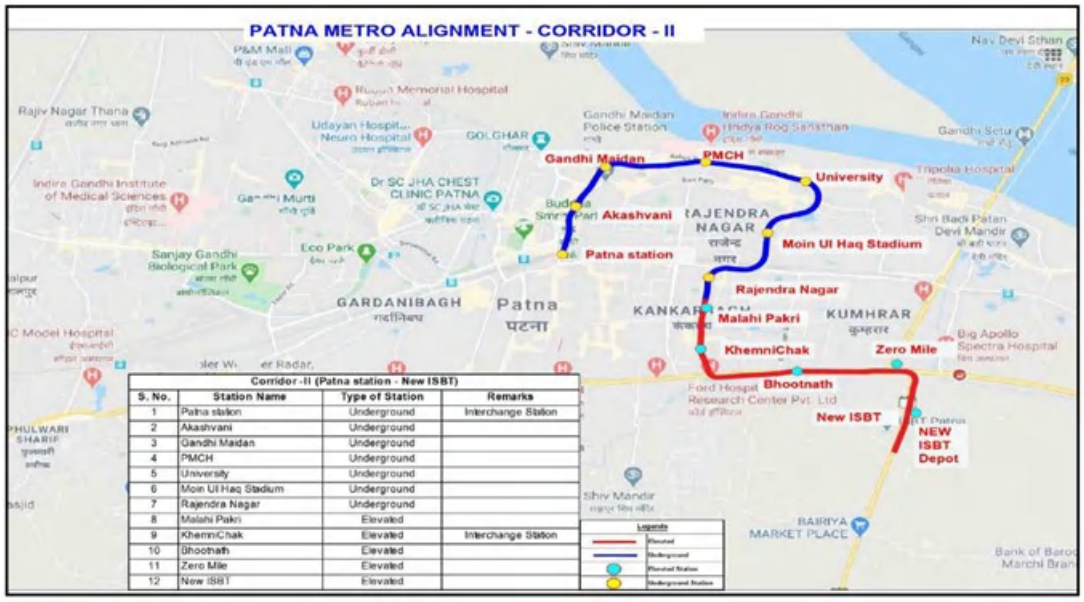



Source: DPR2018

**Figure 14-13: Outline of Route for Alternative 2**

### 3) Alternative 3

Alternative 3 passes through Gandhi Maidan, PMCH, University and Rajendra Nagar. It has the underground section between Patna and Rajendra Nagar stations and the other section up to New ISBT station is planned as an elevated section. After Rajendra Nagar station, the underground section has the transition to the viaduct at Doctor's colony near Malahi Pakri. Thereafter, Malahi Pakri, Khemni Chak, Bhootnath and Zero Mile stations will be elevated sections, terminating at the end of the line. A DEPOT is planned near ISBT. PMRCL has a vision to develop a commercial facility in conjunction with the depot. The DEPOT location has been changed from southwest to southeast of the NEW ISBT station as part of the neighbourhood development plan to bring the bus terminal and commercial facilities closer together.




Source: DPR

**Figure 14-14: Outline of Route for Alternative 3**

### (3) Results of comparative study of alternatives

The table below shows the results of the alternatives evaluation with the 5 ratings set from +2 to -2 including Zero. A comparative evaluation shall be adopted, and it assigns +1 or +2 to the more desirable one and -1 or -2 to the less desirable one after comparing the three alternatives. The item of Profitability and Cost shall be evaluated with a double rate compared with the other items as same reason mentioned in the comparative study of Corridor 1. The total score was calculated for each alternative. As a result of the overall evaluation, Alternative 3 was assessed as the best option.

**Table 14-12: Comparative study results of alternatives**

| No. | Comparative study item | Alternative 1. (Case in which the project is not implemented) | Alternative 2 | Alternative 3. (Adoption proposal) |
|---|---|---|---|---|
| **Project component** | | | | |
| 1 | Beginning point of route | - | Patna Station | Patna Station |
| 2 | End point of route | - | New ISBT | New ISBT |
| 3 | Length of route | - | 14.45 km | 14.564 km |
| 4 | Route | - | Fraser Rd<br>Gandhi Maidan Rd<br>Ashok Rajpath Rd<br>Nara Rd<br>Arya Kumar Rd<br>Kankarbagh Main Rd<br>Chapra Highway<br>Bodhgaya Rd | Fraser Rd<br>Gandhi Maidan Rd<br>Ashok Rajpath Rd<br>Moin Ul Hap<br>Kankarbagh Main Rd<br>Malahi Pakri Rd<br>90 Feet Rd<br>Patna – Sitamarhi Rd<br>Bodhgaya Rd |
| 5 | Number of stations | - | 12 Stations | 12 Stations |

| No. | Comparative study item | Alternative 1. (Case in which the project is not implemented) | Alternative 2 | Alternative 3. (Adoption proposal) |
|---|---|---|---|---|
| 6 | Length of elevated section | - | 9.99 km<br>Some transitional sections to underground are planned. A part of crossing road is divided by the transitional section. | 6.638 km<br>One transitional section to underground is planned. However, this location hardly divide the crossing road. |
| 7 | Number of elevated stations | - | 9 Stations<br>Given Patna station planned as the elevated station, the passenger is forced to go up and down to transfer from/to the underground station of Corridor 1. Therefore, the passenger's convenience is deemed inferior. | 5 Stations<br>Given Patna station planned as the underground station, the passenger's convenience in terms of transfer from/to Corridor 1 is superior to Alternative 2. |
| 8 | Length of underground section | - | 4.55 km | 7.926 km |
| 9 | Number of underground stations | - | 3 Stations<br>A smaller number of underground stations is deemed an advantage in terms of the project implementation. | 7 Stations<br>A larger number of underground stations is deemed a disadvantage in terms of road congestion by the construction and the project costs. |
| 10 | At Grade section | - | 0km | 0km |
| 11 | Ground Level Station | - | - | - |
| 12 | Number of depots | - | 1 Location | 1 Location |
| **Environmental and social considerations** | | | | |
| 13 | Air Quality | Further deterioration by increased traffic is expected. | Improvement by reduced traffic volume is expected. | Improvement by reduced traffic volume is expected. |
| | Rating | -1 | +2 | +2 |
| 14 | Noise and vibration | Noise and vibration from traffic and horns would be worsened. | Noise emissions can be reduced by installing countermeasures | Noise emissions can be reduced by installing countermeasures. |
| | Rating | -1 | +2 | +2 |
| 15 | Earthquake/Flooding・Submergence | - | Although there is a risk of earthquake/flooding・submergence, the damage can be prevented by a countermeasures such as seismic retrofitting and raising the entrance/exit level. | Although there is a risk of earthquake/flooding・submergence, the damage can be prevented by a countermeasures such as seismic retrofitting and raising the entrance/exit level. |
| | Rating | 0 | 0 | 0 |
| 16 | Number of affected trees | - | 705 trees | 506 trees |
| | Rating | 0 | -2 | -1 |
| 17 | Affected historical structure | - | 4 structures<br>Archaeological verification is required and it takes time to implement the project. | - |
| | Rating | 0 | -2 | 0 |

| No. | Comparative study item | Alternative 1. (Case in which the project is not implemented) | Alternative 2 | Alternative 3. (Adoption proposal) |
|---|---|---|---|---|
| 18 | Land acquisition area (However, the temporary construction area and the depot are excluded.)<br>Breakdown of land by owner (However, the temporary construction area and the depot are excluded.) | - | 8.17ha<br>*In addition, Alternative 2 needs 12.50ha of another land acquisition for the depot connected to Corridor 2. A total of 20.66ha needs to be acquired.<br>Central Government Land 1.09 ha<br>State Government Land 5.79 ha<br>Private Land 1.29 ha | 6.65ha<br>*In addition, Alternative 3 needs 19.60ha of another land acquisition for the depot connected to Corridor 2. A total of 26.25ha needs to be acquired.<br>Central Government Land 2.90 ha<br>State Government Land 1.88 ha<br>Private Land 1.87 ha |
| | Rating | 0 | -1 | -2 |
| 19 | PAPs and PAFs (The number includes PAFs not subjected to the resettlement.) | - | 295 persons (56 families)<br>*This number is from Corridor 2 and the depot. | 463 persons (94 families)<br>*This number is from Corridor 2 and the depot. |
| | Rating | 0 | -1 | -2 |
| 20 | Affected structure | - | 118 structures | 83 structures |
| | Rating | 0 | -2 | -1 |
| 21 | Traffic safety | Low | High | High |
| | Rating | -2 | +2 | +2 |
| 22 | Climate change | Increase in $CO_2$ emission is expected due to higher traffic volume. | Decrease in $CO_2$ emission is expected due to lower traffic volume. However, it incurs $CO_2$ emission from the electricity generation to operate the metro. | Decrease in $CO_2$ emission is expected due to lower traffic volume. However, it incurs $CO_2$ emission from the electricity generation to operate the metro. |
| | Rating | -2 | +1 | +1 |
| 23 | Number of transition section from elevated to underground (Community severance) | - | 2 | 1 |
| | Rating | 0 | -2 | -1 |
| **Connectivity** | | | | |
| 24 | Enhancement of transfer convenience between Corridor 1 and 2 at Patna Station by undergrounding Patna St. of Corridor 2 | - | The two corridors are connected in the different level, which will force passengers more than 30 meters vertical movement for transfer and will take 8 minutes for transferring. | The two corridors are connected at the same level but passengers must pass through the concourse for transferring which will take 2-3 minutes, and its vertical movement could be less than 10 meter.<br>The transfer can be done in the underground, which is much comfortable for passengers. |
| | Rating | 0 | -1 | +1 |

| No. | Comparative study item | Alternative 1. (Case in which the project is not implemented) | Alternative 2 | Alternative 3. (Adoption proposal) |
|---|---|---|---|---|
| 25 | Enhancement of transfer convenience by connection improvement between Patna Metro and IBST, Rajendra nagar St. | - | There are 4 inter-stations between the IBST and Rajendra Nagar St. There are 10 stations between the IBST and Patna St. | The distance between the IBST and Rajendra Nagar St. is not different, however, the distance between the IBST and Patna St. comes 7 stations, which will shorter than Alt. 2, though it requires transferring at Khemni Chak. |
| | Rating | 0 | +1 | +2 |
| **Profitability** | | | | |
| 26 | Advantage and profitability improvement for passenger growth | - | The alignment runs along the Indian Railway corridor, where has low accessibility to the surrounding area and low growth potential.<br>2024 373,460 pax/day<br>2031 588,104 pax/day<br>2041 662,445 pax/day<br>2051 773,133 pax/day | The alignment runs along the National Highway and Malahi Pakri, where has high development potential to the Alt. 2 corridors.<br>2024 443,829 pax/day<br>2031 674,160 pax/day<br>2041 728,604 pax/day<br>2051 811,947 pax/day |
| | Rating | 0 | +2 | +4 |
| **Cost** | | | | |
| 27 | Project cost | - | Given the viaduct section towards the beginning point of the route, the project cost is lower than Alternative 3. | Given that the underground section is longer than Alternative 2, the project cost is higher than it. |
| | Rating | 0 | -2 | -4 |
| **Evaluation** | | -6 | -3 | +3 |
| | | 3rd | 2nd | 1st |

Source: DPR, Social Impact Assessment 2020, DMRC, JST

### (4) Sensitivity Analysis

To assess the suitability of the weighting of the indicators for Environmental and social considerations, and cost-effectiveness, a sensitivity analysis was conducted as shown in the table below same as Corridor 1. As a result, it was confirmed that any change in the weighting of the relevant indicators would not affect the selection of the preferred alternative.

**Table 14-13: Sensitivity analysis result for the indicators of cost-effectiveness**

| Weighting for Indicators of environmental items compared to cost-effectiveness items | Ranking (Evaluation point) | | |
|---|---|---|---|
| | Alternative 1 | Alternative 2 | Alternative 3 |
| Half (0.5) | 3rd (-3) | 2nd (-1.5) | 1st (+1.5) |
| Same (1.0) | 3rd (-6) | 2nd (-3) | 1st (+3) |
| Double (2.0) | 3rd (-12) | 2nd (-6) | 1st (+6) |
| Triple (3.0) | 3rd (-18) | 2nd (-9) | 1st (+9) |
| **Weighting for Indicators of cost-effectiveness compared to environmental items** | **Alternative 1** | **Alternative 2** | **Alternative 3** |
| Half (0.5) | 3rd (-6) | 2nd (-3) | 1st (+3) |
| Same (1.0) | 3rd (-6) | 2nd (-3) | 1st (+3) |
| Double (2.0) | 3rd (-6) | 2nd (-3) | 1st (+3) |
| Triple (3.0) | 3rd (-6) | 2nd (-3) | 1st (+3) |

Source: JST

### (5) Validation of route selection

#### 1) Beginning point side section (Patna - Premchandra, Moin UL HAQ)

The same section has been selected for both Alternatives 2 and 3. While the Patna - PMCH section is an underground section and the road as the space for the railway is relatively wide, the PMCH - Rajendra Nagar section is narrow and there are no suitable roads along the route. Thus, the majority of the section passes under private land. The surrounding area is densely populated with low-rise residential buildings and small shops, and there are several large hospitals and universities on the route. Corridor 2 will have stations near these public facilities, therefore the high passenger demand is expected. Considering the current situation where road traffic is currently disrupted by narrow roads and it is difficult for buses to operate smoothly, the introduction of the subway is highly recommended to mitigate the situation. However, due to heavy road traffic and narrow roads, the construction of the subway will be very difficult.

Reasons for selection of alternative.

- Undergrounding is recommended to reduce the number of transitions due to concerns about the fragmentation of the crossroads caused by multiple underground transitions.

#### 2) Intermediate section (Premchandra, Moin UL HAQ – Zero Mile)

Alternative 2 and Alternative 3 have different routes in this section.

Alternative 2 follows the Indian Railways line from Rajendra Nagar station to the east on Kankarbagh Main Rd and then it goes to southwards along Chapra Highway from Gandhi Setu station up to Zero Mile station. The section along the Indian Railways Line has no stations on the Indian Railways Line except Rajendra Nagar Station. The Indian Railways Line runs on a level section and there are few points to cross the Indian Railways Line on the section where it runs alongside Corridor 2 as there are only two pedestrian bridges. Therefore, in addition to the Rajendra Nagar station, which will be the junction station with the Indian Railways, the Nalanda Medical College station and Kumhrar station are planned, but unless crossing the Indian Railways is provided, access to the station from the surrounding areas will

be divided by the Indian Railways and the station area will be limited to the southern half of the station. Passenger demand on this section is expected to be small, as the area between Gandhi Setu and Zero Mile Station is an area with a relatively low concentration of small factories along the road and a relatively low concentration of residential dwellings. There are also four affected historic buildings and sites on this section of the alternative (see 2.5.9). If Alternative 2 is adopted, archaeological verification would be required, making it difficult to realize the project as quickly as possible. Alternative 3 would run from Rajendra Nagar Station southwards on Malahi Pakri Rd, 90 Feet Rd via Malahi Pakri Station to Khemni Chak Station, which is the connecting station with Alternative 3 on Corridor 1. After Khemni Chak station, the route continues eastwards on Patna - Sitamarhi Rd with Bhootnath station on the way and rejoins the Alternative 2 route near Zero Mile station.

Reasons for selection of alternatives.

- Early commencement of the project, avoiding the archaeological inspection period due to the proximity of historic buildings.
- Advantages in terms of user growth due to the degree of concentration of housing along the line.

### 3) End of the Lines side section (Zero Mile – New ISBT)

Although both Alternatives 2 and 3 have the same route for the section from Zero Mile station to the terminus, the location of the rail depot near the New ISBT station at the end of the line is south-west of the New ISBT station in Alternative 2 and south-east of the New ISBT station in Alternative 3, with the rail depot located in a different position. After the Zero Mile station, the line travels south on Bodhgaya Rd to the New IBST station. While the area around this section is a suburb of Patna City with arable land and sparse housing, a bus terminal is located adjacent to the terminus New IBST station. Although the bus terminal is still partially under construction, it is very large and long-distance buses from all over the country arrive at and depart from this terminal and the surrounding roads are heavily congested with passengers and buses. Currently, the only access to the bus terminal is by road transport such as local buses or auto-rickshaws, therefore there is an urgent need to develop rail-based transport in the Patna area. In particular, bus users' accessibility to the Indian Railways station needs to be improved through the conversion from the road transportation as soon as possible in order to mitigate the congestion on the city roads compared with zero option (without project) due to the relocation of bus users from road transport into and out of the city.

Reasons for selection of alternatives,

- Reduction of road traffic into the city by improving transport connections between the bus terminal and the city.
- Improved convenience for bus terminal users by connecting them to the Indian Railways station.




Source: DPR2018, 2021, PMRCL, JST

**Figure 14-15: Comparison of Corridor-2**

### (6) Conclusions from the comparison of alternatives

In the comparison between Alternatives 2 and Alternative 3, the only difference would be the intermediate section when focusing on Corridor 2. Either alternative can achieve the purpose of the project which is to construct the rail-based transport to reduce road traffic coming into the city by connecting suburban bus terminals and Indian Railways Line stations. However, when considering the linkage with Corridor 1, Alternative 3 allows for a junction station at Khemni Chak station and also it does not need the depot exclusively used for Corridor 1 since Corridor 2 depot can be shared. This would reduce the impact on the surrounding environment and lower the overall project cost.

In addition, Alternative 2 passes through a historical district in some sections for which requires a period of archaeological verification work. Therefore, it is presumed that the project cannot proceed as soon as possible though Corridor 2 should be constructed urgently, and Alternative 3 also can ensure the convenience for more citizens of Patna by avoiding competing sections with Indian Railways between Rajendra Nagar to Gulzarbagh Given with the above information, Alternative 3 has to be selected even if the land acquisition area for Alternative 3 increases compared to Alternative 2. However, the number of cutting trees and affected structures is significantly lower than Alternative 2. Therefore, it is concluded that Alternative 3 has the high advantage in overall.

### 14.4.3 Depot

#### (1) Results of comparative study of alternatives

The table below shows the results of the comparison of the depot alternatives with the 5 ratings set from +2 to -2 including Zero. A comparative evaluation shall be adopted, and it assigns +1 or +2 to the more desirable one and -1 or -2 to the less desirable one after comparing the two alternatives. The item of Cost shall be evaluated with a double rate compared with the other items as same reason mentioned in the comparative study of Corridor 1 and 2. The total score was calculated for each alternative same as Corridor 1 and 2. As a result of the overall evaluation, Alternative 3 was assessed as the best option. Due to the selection of the Corridor 1 and Corridor 2 alternatives, Alternative 3 will be adopted for the depot, and the comparison of the depots in each alternative will be verified. As the environmental and social considerations in the depot comparison are included in the comparison for Corridors 1 and 2, this section also compares the size of the facilities and examines the possibility of locating the depot in other areas.

**Table 14-14: Comparative study results of Depot alternatives**

| No. | Comparative study item | Alternative 2 | | | Alternative 3. Total of Corridors 1 and 2 (Adoption proposal) |
|---|---|---|---|---|---|
| | | Corridor 1 | Corridor 2 | Total of Corridors 1 and 2 | |
| 1 | Location | Terminus of Corridor 1 Mithapur station 3 km south point Aitwarpur | Terminus of Corridor 2 Southwest side of New ISBT station | - | Terminus of Corridor 2 Southwest side of New ISBT station |
| 2 | Name of the depot | Aitwarpur Depot | New ISBT Depot | - | New ISBT Depot |
| 3 | Area of depots | 14.4ha | 12.5ha | 26.9ha | 19.6ha |
| 4 | Total length of tracks in depots | 11.4km | 9.1km | 20.5km | 9.0km |
| 5 | Number of trains | 41 trainsets (1 trainset / 3 cars) | 26 trainsets (1 trainset / 3 cars) | 67 trainsets (1 trainset / 3 cars) | 64 trainsets (1trainset / 3 cars) |
| 6 | Number of trains to be parked | 40 trainsets Night parking at station: 1 trainset | 24 trainsets Night parking at station: 1 trainset Night parking at inspection line: 1 trainset | 64 trainsets Night parking at station: 2 trainsets Night parking at inspection line: 1 trainset | 64 trainsets |
| 7 | Number of stabling lines | 20 lines 1 line / 2 trainsets | 12lines 1 line / 2 trainsets | 32 lines 1 line / 2 trainsets | 16 lines 1 line / 4 trainsets |
| 8 | Stabling line effective length | 160m | 160m | 160m | 331m |
| 9 | Number of inspection lines | 4 lines | 4 lines | 8 lines | 4 lines |
| 10 | Number of workshop lines | 4 lines | 4 lines | 8 lines | 4 lines |
| 11 | Number of indoor-type car washing line | 1 line | 1 line | 2 lines | 1 line |
| 12 | Number of wheel lathe line | 1 line | 1 line | 2 lines | 1 line |
| 13 | Test track | 850m 1 line | 800m 1line | 2 lines 1,650m | 739m 1 line |

| No. | Comparative study item | Alternative 2 | | | | | | Alternative 3. Total of Corridors 1 and 2 (Adoption proposal) | |
|---|---|---|---|---|---|---|---|---|---|
| | | Corridor 1 | | Corridor 2 | | Total of Corridors 1 and 2 | | | |
| 14 | Administration office | 1 building | | 1 building | | 2 buildings | | 1 building | |
| 15 | Train operators booking office | 1 building | | 1 building | | 2 buildings | | 1 building | |
| 16 | Capacity of power receiving facility | 2,500KVA | | 2,500KVA | | 5,000KVA | | 2,500KVA | |
| **Environmental and social considerations** | | | | | | | | | |
| 17 | Land use status | Central Government Land | 0 | Central Government Land | 0 | Central Government Land | 0 | Central Government Land | 0 |
| | | State Government Land | 0 | State Government Land | 0 | State Government Land | 0 | State Government Land | 0 |
| | | Private Land | 14.4ha | Private Land | 12.5ha | Private Land | 26.9ha | Private Land | 19.6ha |
| | Rating | - | | - | | -2 | | -1 | |
| 18 | Affected structures | 14 structures | | 6 structures | | 20 structures | | 23 structures | |
| | Rating | - | | - | | -1 | | -1 | |
| 19 | Earthquake/Flooding・Submergence | - | | - | | Although there is a risk of earthquake/ flooding/ submergence, the damage can be prevented by a countermeasures such as compaction on embankment and foundation. | | Although there is a risk of earthquake/ flooding/ submergence, the damage can be prevented by a countermeasures such as compaction on embankment and foundation. | |
| | Rating | - | | - | | 0 | | 0 | |
| **Project cost** | | | | | | | | | |
| 20 | Project cost | - | | - | | The project cost is higher than Alternative 3 due to two depots needed. | | The project cost is lower than Alternative 2 due to only one depot needed. | |
| | Rating | - | | - | | -4 | | -2 | |
| **Evaluation** | | -7 | | | | | | -4 | |
| | | 2nd | | | | | | 1st | |

Source: DPR2018, 2021, DMRC, JST

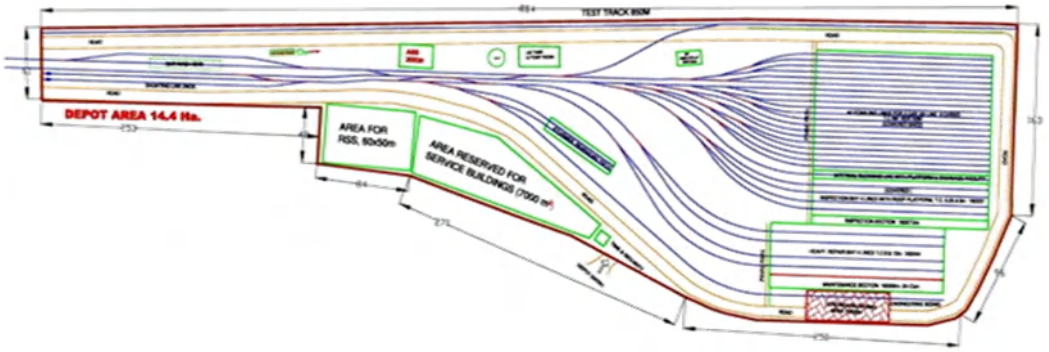
## (2) Sensitivity Analysis

To assess the suitability of the weighting of the indicators for Environmental and social considerations, and cost-effectiveness, a sensitivity analysis was conducted as shown in the table below same as Corridor 1 and 2. As a result, it was confirmed that any change in the weighting of the relevant indicators would not affect the selection of the preferred alternative.

**Table 14-15: Sensitivity analysis result for the indicators of cost-effectiveness**

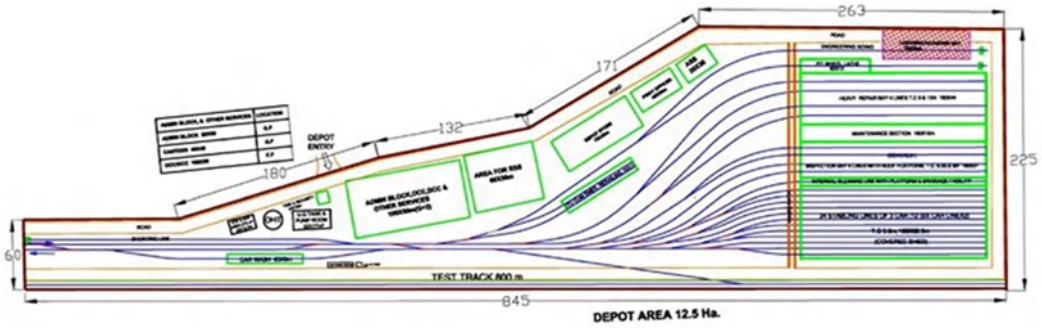
| Weighting for Indicators of environmental items compared to cost-effectiveness items | Ranking (Evaluation point) | |
|---|---|---|
| | Alternative 2 | Alternative 3 |
| Half (0.5) | 2nd (-5.5) | 1st (-3) |
| Same (1.0) | 2nd (-7) | 1st (-4) |
| Double (2.0) | 2nd (-10) | 1st (-6) |
| Triple (3.0) | 2nd (-13) | 1st (-8) |
| **Weighting for Indicators of cost-effectiveness compared to environmental items** | **Alternative 2** | **Alternative 3** |
| Half (0.5) | 2nd (-5) | 1st (-3) |
| Same (1.0) | 2nd (-7) | 1st (-4) |
| Double (2.0) | 2nd (-11) | 1st (-6) |
| Triple (3.0) | 2nd (-15) | 1st (-8) |

Source: JST



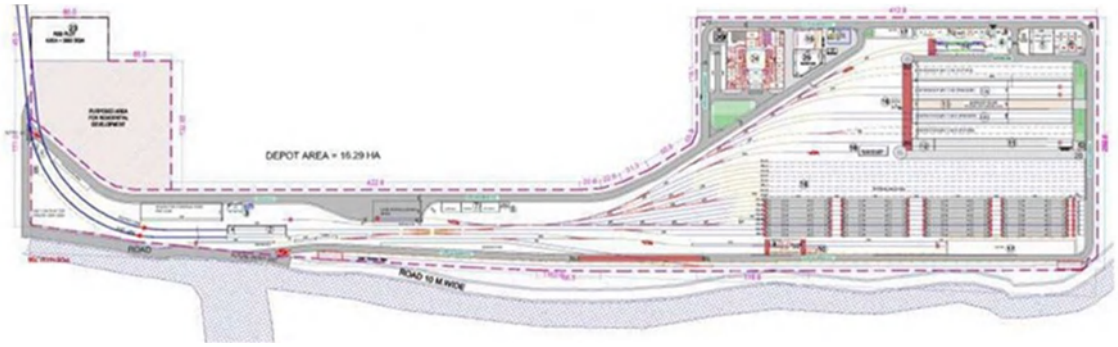

Source: DPR2018

**Figure 14-16: Alternative 2 Aitwarpur Depot Plan**




Source: DPR2018

**Figure 14-17: Alternative 2 New ISBT Depot Plan**




Source: DPR

**Figure 14-18: Alternative 3 New ISBT Depot Plan**

### (3) Results of comparison of depot facility sizes

#### 1) Depot layout policy

Given that Corridor 1 and Corridor 2 are separated in Alternative 2, the depot also needs to be separately located at Aitwarpur and New ISBT likewise. Except for the storage track which depends on the number of train set to be accommodated, both depots have the same facility since each depot has to independently handle the train parking and the maintenance work.

On the other hand, in case of Alternative 3, is the depot at New ISBT has to accommodate and carry out the maintenance for all trains of Corridor 1 and Corridor 2.

#### 2) Number of Train-set

Under Alternative 2, 41 train-sets on Corridor 1 and 26 train-sets on Corridor 2 would be operated thus, a total of 67 train-sets would be operated. In contrast, Alternative 3 would operate 64 train-sets, which is three train-sets less than Alternative 2. The number of train-sets in operation would increase since the overall route length would be approximately 1 km longer on Corridor 1 under Alternative 3. However, the total number of train-sets including operational as well as non-operational would be less than Alternative 2 since the number of train-sets for backup could be reduced through the integration of depots.

#### 3) Total track length in the depot

In Alternative 2, the track length in depot is 20.5 km, whereas in Alternative 3 it is halved to 9.0 km. The main reasons for the halving are that the overall number of storage tracks has been reduced in Alternative 3 as four train-sets can park on one storage track. Moreover, the less number of storage tracks, results in a significant reduction in track length of the approach section from the turnout to the storage track. Although the number of turnouts is not mentioned, a reduction in the overall number of turnouts is achieved in Alternative 3 through the integration of depot.

#### 4) Number of inspection lines and workshop lines in the depot

The number of inspection lines and workshop lines is halved in Alternative 3 compared to Alternative 2. Although there is an increase in capacity under Alternative 3, the number of lines per depot does not increase from the number of lines per depot under Alternative 2 when the depots are merged because of

the spare inspection capacity at each depot under Alternative 2.

5) Conclusions on the scale of facilities resulting from the integration of depots

Alternative 2 has depots for each Corridor 1 and Corridor 2, which meant that the necessary facilities have to be established at each of the two depots whereas the integration of depot proposed in Alternative 3 can centralize the depot facilities without increasing the size of the individual facilities. In conclusion, decentralizing the depot functions is to double the facilities, whereas it should be centralized into one depot with an appropriate size as proposed in Alternative 3. Therefore, it is concluded that it is reasonable to choose the Alternative 3 that demonstrates economies of scale, such as reduction of land acquisition area and integration of duplicated facilities.

### (4) Verification of the adequacy of the location of the depot

From the viewpoint of the train operation, it is preferable f to locate the depot at the end of the line. It also another benefit for reducing operating costs since it can reduce the construction costs of the connecting line and reduce the power costs associated with the spur line from/to the depot.

Three locations were proposed in the study of alternatives, namely the Aitwarpur depot on Corridor 1, and the New ISBT depot on Corridor 2 (south-west of the New ISBT station) in Alternative 2, and the New ISBT depot on Corridor 2 (south-east of the New ISBT station) in Alternative 3. Finally, the New ISBT depot (south-east of New ISBT station) was selected.

1) Aitwarpur depot

The Aitwarpur depot is proposed for a case that Mithapur station is planned as the terminus. This location is not recommended since the distance from the terminus station to the depot is long. In addition, the terminus has been changed from Mithapur Station to Khemni Chak Station as Alternative 3 for Corridor 1 is selected as the optimal plan. Therefore, this location is no longer connected to the terminus. Considering the complicated operation for Corridor 2 train entering to/departing from the depot, there is no positive reason to recommend the Aitwarpur depot.

2) New ISBT depot (New ISBT St. south-west)

It is located south-west of the New ISBT station but is slightly further away from the station than New ISBT station south-east which is described below. There are no technical problems with the adoption of this proposal, but it is slightly less favorable due to the longer spur line from the depot to the main line compared to New ISBT station south-east.

3) New ISBT depot (New ISBT St. south-east)

Located on the southeast side of the New ISBT station, it is close to and almost adjacent to the station, and the extension of the connecting line will be minimal.

The depot and the bus terminal on the opposite side of the station are planned to be integrated into a single commercial facility, which will be advantageous from the standpoint of increasing the number of rail and bus users.

4) Possibility of installing depots at other locations

The most desirable location for a rail depot would be near the end of the line. The following three stations are possible locations for the depot other than three aforementioned locations.

- Near Danapur station
- Near Patna station
- Near Khemni Chak station

To locate a depot near Danapur station seems not realistic since it forces a train by out-of-service for long distance. The location near Patna station is also difficult since it requires the large scale structure for the spur line due to the underground main line. It also has the difficulty in the land acquisition.

Khemni Chak Station, where Corridor 1 and Corridor 2 are connected, has a cultivated area at the southeast of the station. Whereas it is far from the station, there would be relatively few problems with land acquisition and train operations. However, there is the advantages that the connecting line would be longer. Figure 14-19 Schematic diagram of the location of the Khemni Chak station connecting depot shows the location of the relevant sections.

As a depot other than proposed in the alternative plan, a case of locating it on the south-east side of Khemni Chak station is envisaged. However it is difficult to change the New ISBT depot (south-east of New ISBT station) where the residents' explanation of land acquisition and construction preparations are in progress.




Source: JST based on Google earth

**Figure 14-19: Schematic Diagram of the Location of the Khemni Chak Station Connecting Depot**

### 14.4.4 Issues from a train operation perspective

Based on the results of the comparison of Alternative 2 and Alternative 3, the latter was selected for both Corridor 1 and Corridor 2. From the viewpoint of the train operation, the issue of Alternative 3 is the alignment in the premise of Khemni Chak station. The current alignment at Khemni Chak station is arranged

with Corridor 1 to the north and Corridor 2 to the south. Corridor 1 operation basically terminates at Khemni Chak station and it has no revenue service to New IBST station on Corridor 2. Whereas Corridor 1 and Corridor 2 are connected at the east of Khemni Chak station, this level crossing is over the main line and only trains travelling to and from the depot are allowed to proceed from Corridor 2 to Corridor 1 through this level crossing. Therefore, it is not recommended that trains from New IBST station enter to Corridor 1 through Corridor 2 in the operation hours due to the high risk of train delays caused. This advantage will be an issue how to respond to future changes in passenger demand. In addition, although passengers travelling from New IBST to Patna Station can eventually reach the destination without the transfer, it would be much faster if they transfer to Corridor 1 at Khemni Chak Station with considering the short distance to Patna Station. However, the current alignment forces the passenger to go up and down to transfer since the platform of Corridor 1 and Corridor 2 are arranged at different level, which may let the passengers to reluctant to transfer. Although it is recommended to change the alignment to arrange both platforms at the same level for more convenient transfer, Khemni Chak station has been in progress and some piers have already been built as of June 2022. Given such a situation, it is not realistic to change the alignment with structural changes at this stage. Therefore, the issue raised in this section is described to improve the future extension plans.

## 14.5 Scoping pertaining to Environmental and Social Considerations

This section summarizes the scoping for the prioritized alternative concluded in the preceding section, assuming positive and negative environmental and social impacts based on the information obtained from site reconnaissance and existing literature.

### 14.5.1 Scoping

The scopes of Environmental and Social considerations are the construction of the main structure including viaducts, railway tracks, elevated and underground stations, a depot, and receiving substations. The table below shows the affected environmental and social items, the so-called scoping results. The other table also shows the scoping result for the related facilities such as borrow-pit, quarry and construction yard. However, the scoping result at the operation stage for the related facilities should be omitted because they are for use only during the construction, and the responsibility for preparing EMP and EMoP of the facilities belongs to PMRCL as the project proponent and their construction contractor. Based on the detailed design prepared by PMRCL, the contractor will formulate a construction plan including the details of the related facilities at the construction stage, and will commence using the facilities after approval by the Government of India.

## Table 14-16: Scoping for the Project Facilities with Reasons Evaluated

| No | Impact item | Evaluation | | Reason for evaluation |
|---|---|---|---|---|
| | | Pre-CS CS | OS | |
| **Pollution** | | | | |
| 1 | Air pollution | ✓ | | **CS:** Emission gas (NOx, SOx) and dust (SPM) are caused temporarily by some heavy machines and dump trucks. |
| | | | | **OS:** Positive impact will be offered by the decrease of traffic along the Corridors. |
| 2 | Water pollution | ✓ | ✓ | **CS:** - Turbid water will be generated in surface water and ground water along the Corridors due to civil and excavation works.<br>- Turbid water will be generated at a proposed site for depot due to soil filling works.<br>- There is a possibility of being discharged with organic wastewater at an installed base campsite. |
| | | | | **OS:** There is a possibility of discharged organic wastewater from the toilet installed at every station and the depot. |
| 3 | Waste | ✓ | ✓ | **CS:** - It is predicted that construction waste such as soil and felled trees is generated.<br>- General waste and excreta will be generated from the base campsite. |
| | | | | **OS:** - General waste and excreta will be generated from every station and a depot, etc. |
| 4 | Soil contamination | ✓ | ✓ | **CS:** - Excavated soil at the construction site may be contaminated.<br>- Oil leaks from constriction equipment may cause soil contamination. |
| | | | | **OS:** - Soil contamination may be generated at the proposed depot due to oil leaks of heavy machine and rolling stock coating.<br>- Inappropriate management of transformer will cause oil leakage. Consequently, it will contaminate the soil. |
| 5 | Noise and vibration | ✓ | ✓ | **CS:** Noise and vibration will be generated by construction heavy machines, dump trucks, concrete placing work, and traffic congestion due to traffic control. |
| | | | | **OS:** Patna Metro can contribute to reducing traffic noise and vibration through traffic volume reduction, but Patna Metro may emit additional noise and vibration from its operation. |
| 6 | Ground subsidence | ✓ | ✓ | **CS/OS:** Construction activities that have a negative impact on underground water such as large-scale digging and water pumping are not scheduled in this project. But there is still a possibility of ground subsidence in case the foundation under the elevated section is soft. |
| 7 | Offensive odor | ✓ | ✓ | **CS:** Offensive odor may be emitted depending on the volume of general waste from basecamp sites. |
| | | | | **OS:** Offensive odor may be emitted depending on the volume of general waste from every station and depot. |
| 8 | Bottom Sediment | | | **CS/OS:** No impact on Bottom Sediment is expected because all crossing river sections are underground. |
| **Natural Environment** | | | | |
| 9 | Protected area | ✓ | ✓ | **CS/OS:** Although SGB Park is designated as a protected area, it is managed by the Government of Bihar as Park-cum-Zoo, whose management type is different from that of other natural protected areas which risks disorderly destruction. However, there may be indirect impacts on fauna and flora at the construction stage and operation stage. |
| 10 | Ecosystem | ✓ | ✓ | **CS:** - There is a negative impact on the ecosystem through the deforestation of trees due to the construction of viaducts, underground stations and a depot.<br>- Since a partial section pass through Danapur Cantonment KBA, the impact on the ecosystem is expected.<br>- A negative impact on the ecosystem may occur due to the construction of a depot. |
| | | | | **OS:** Since a partial section pass through Danapur Cantonment KBA, the impact on the ecosystem is expected. |

| No | Impact item | Evaluation | | Reason for evaluation |
|---|---|---|---|---|
| | | Pre-CS CS | OS | |
| 11 | Hydrology | ✓ | | **CS:** - Construction activities that have a negative impact on underground water such as large-scale digging and water pumping are not scheduled in this project. However, some impact on hydrology around the project site will occur in case of high groundwater level.<br>- Since a river flows along the south of the depot candidate site, the depot construction may affect the surrounding hydrology. |
| | | | | **OS:** Construction activities which have a negative impact to underground water, such as large- scale digging and water pumping, are not scheduled. |
| 12 | Geology and Topography | ✓ | ✓ | **CS/OS:** There is no specified and valuable geology and topography in and around the alignment. However, there is a possibility of soil erosion and slope collapse due to filling soil for the Depot construction. |
| **Social Environment** | | | | |
| 13 | Land acquisition/ Resettlement | ✓ | ✓ | **Pre-CS:** It is predicted that there are land acquisition and resettlement along the Corridors and in Depot area. |
| | | | | **OS:** Economic displacement may be occurred due to the Metro operation. |
| 14 | Poverty | ✓ | | **Pre-CS:** The impact on poverty is evaluated based on characteristics of local society around the Corridors. |
| | | | | **OS:** Since land acquisition and resettlement will be completed before construction, operation activities that have a negative impact on people with poor class are not expected. |
| 15 | Indigenous and ethnic people | ✓ | | **Pre-CS:** The impact on indigenous and ethnic people is evaluated based on characteristics of local society around the Corridors. |
| | | | | **OS:** Since land acquisition and resettlement will be completed before construction, operation activities that have a negative impact on indigenous and ethnic people are not expected. |
| 16 | Local economy such as employment and livelihood, etc. | ✓ | | **Pre-CS/CS:**<br>- A negative impact on the livelihood of PAPs may be generated depending on land acquisition and resettlement.<br>- With opening of Patna Metro, drivers of route buses and three wheelers, which are overlapping their operation area of transportation, may suffer negative impacts on their livelihoods. |
| | | | | **OS:** - New employment may be created with opening of Patna Metro.<br>- A positive impact for the local economy will be generated such as timesaving for traveling within Patna city and alleviation of traffic congestion. |
| 17 | Land use and utilization of local resources | ✓ | ✓ | **CS:** There may be a negative impact on land acquisition for agricultural land in the proposed depot area. |
| | | | | **OS:** There is no land acquisition and resettlement in the operation phase. However, negative impact may be generated if disordered development and rough-and-tumbled utilization of local resources occur around the Corridors and stations. |
| 18 | Water use and its rights | ✓ | | **CS:** Land acquisition and construction work may affect drinking water sources such as wells. |
| | | | | **OS:** There is no impact on water use because of no land acquisition, and there is no additional impact on water use and its rights because irrigation facilities and drinking water facilities such as waterworks and wells located in the project area including viaduct, station building, and the depot can be transferred as necessary. |
| 19 | Existing social infrastructure and services | ✓ | | **CS:** - A negative impact on sensitive facilities such as schools, hospitals, and community centers may occur depending on land acquisition and traffic issues such as congestion and accidents.<br>- The impact of the relocation of underground facilities is expected due to the construction work.<br>- There may be a possibility of electrical power cut temporarily around the alignment when relocation and under installation of high –voltage line is conducted. |
| | | | | **OS:** Improvement of accessibility by installing Patna Metro stations is expected, by which there is a possibility of a positive impact on the use of social infrastructure such as school, hospital, etc. |

| No | Impact item | Evaluation | | Reason for evaluation |
|---|---|---|---|---|
| | | Pre-CS CS | OS | |
| 20 | Social institutions such as social infrastructure and local decision - making institutions | | | **CS:** Since the construction is mainly conducted in the central part of the existing road and underground, there is no possibility of local community severance. |
| | | | | **OS:** There is no community severance because Patna metro will be constructed by elevated and underground structures for all sections. |
| 21 | Maldistribution of benefit and damage | ✓ | ✓ | **CS:** Depending on the construction area, there may be a maldistribution of benefit and damage such as the prohibition of road crossing and setting of the detour route. |
| | | | | **OS:** With opening of Patna Metro, companies of route buses and union of three wheelers, which are overlapping their operation area of transportation, may reduce their operating profit. |
| 22 | Local conflict of interest | ✓ | | **CS:** Residents and municipalities may demand that construction contractor should supply employment opportunities equally as construction workers. |
| | | | | **OS:** It is predicted that there is no local conflict of interest because Patna Metro services are evenly accessible for local communities. |
| 23 | Cultural Heritage | ✓ | ✓ | **Pre-CS/CS:** It is predicted that there is low possibility of impact on religious and historical buildings such as temple under the current proposed alignment. However, impacts should be carefully reviewed. |
| | | | | **OS:** There is no impact on religious and historical buildings because of no-additional land acquisition at the operation stage. However, the impact of vibration from Patna Metro operation should be reviewed. |
| 24 | Landscape | | ✓ | **CS:** - There is no landscape conservation area designated by law and regulation in the vicinity of the elevated section.<br>- Since the construction is mainly conducted in the central part of the existing road and underground, there is no impact on landscape. |
| | | | | **OS:** The everyday landscape in the vicinity of the Corridors will change due to elevated structure, station buildings. |
| 25 | Gender | ✓ | ✓ | **CS:** There may be a gender gap regarding wage, salary, and treatment as construction workers. |
| | | | | **OS:** Employment opportunities for women may be limited concerning Patna Metro operation because the opportunities may not be the same for females despite having the same qualifications and abilities as males. Additionally, female passengers may give up getting on trains for fear of congestion on the train during commuting time. |
| 26 | Children's right | ✓ | | **CS:** Negative impact on children's rights is not estimated by the project, but the impact possibility should be evaluated based on the information collected by the field survey. |
| | | | | **OS:** There is no impact on children's rights by Patna Metro operation. |
| 27 | Health (Infectious diseases such as HIV/AIDS, etc.) | ✓ | ✓ | **CS:** Infectious diseases such as STD, COVID-19, etc. may be spread by the inflow of construction workers. Additionally, Land use changes by soil cutting and soil filling may create new habitats for mosquitoes that can mediate dengue fever. |
| | | | | **OS:** There is a possibility that STD and other infectious diseases spread by increasing the number of settlers and travellers after Patna Metro operation. |
| 28 | Labor environment including labor safety | ✓ | ✓ | **CS:** It is necessary to improve the labor environment for construction workers following related laws and regulations. |
| | | | | **OS:** - There is no big change in the labor environment for residents by Patna Metro operation.<br>- The appropriate labor environment for working staff needs to be secured following related laws and regulations. |

| No | Impact item | Evaluation | | Reason for evaluation |
|---|---|---|---|---|
| | | Pre-CS CS | OS | |
| **Others** | | | | |
| 29 | Accidents | ✓ | ✓ | **CS:** Since construction-related vehicles use arterial roads on the Corridors, there is a possibility of increasing traffic accidents. |
| | | | | **OS:** It is estimated that the risk of traffic accidents will maintain due to increased vehicle velocity by reducing traffic volume. |
| 30 | Cross-border impact and climate change | ✓ | ✓ | **CS:** Greenhouse gas emissions will increase slightly by cutting street trees along the Corridors, operation of construction heavy machinery, and construction of structures. |
| | | | | **OS:** Since the traffic volume along the Corridors will reduce due to Patna Metro operation, the reduction of greenhouse gases can be expected. On the other hand, it is also conceivable that greenhouse gases will be generated due to the electric consumption by Patna Metro operation. |

Note: ✓: Items to be assessed, Pre-CS: Pre-Construction Stage, CS: Construction Stage, OS: Operation Stage

Source: JST

## Table 14-17: Scoping for the Related Facilities (Quarry, Borrow-Pit, and Construction Yard) with reasons for Evaluation

| No. | Impact item | Evaluation | Reason for evaluation |
|---|---|---|---|
| | | CS | |
| **Pollution** | | | |
| 1 | Air pollution | ✓ | Emission gas (NOx, SOx) and dust (SPM) are caused by some machines and dump trucks temporarily. |
| 2 | Water Pollution | ✓ | If the drainage is undeveloped, it may affect the surrounding water sources during rainfall. |
| 3 | Waste | ✓ | Surplus materials will be generated. |
| 4 | Soil contamination | ✓ | Temporary soil contamination due to oil leakage that may be caused by using fuel for heavy machines and vehicles. |
| 5 | Noise and vibration | ✓ | Noise and vibration are caused by construction heavy machinery and dump trucks. |
| 6 | Ground subsidence | | No activity that will cause land subsidence is expected. |
| 7 | Offensive odor | | No activity that will cause offensive odor is expected. |
| 8 | Bottom Sediment | | No activity that will deteriorate bottom sediment is expected. |
| **Natural Environment** | | | |
| 9 | Protected area | ✓ | If there are protected areas in the vicinity of the related facilities, it may affect the conservation area. |
| 10 | Ecosystem | ✓ | If the need for soil and crushed stones exceeds the expectations, the excavation range may be expanded and the ecosystem may be affected. There is also a possibility of logging trees. |
| 11 | Hydrology | | No activity that will cause changes to hydrology is expected. |
| 12 | Geography and topography | ✓ | If the valuable geography and topography exist in the vicinity of the related facilities, it may affect geography and topography. |
| **Social Environment** | | | |
| 13 | Land acquisition/ Resettlement | | As a basic policy, the registered site by the local government should be utilized, so there will be no land acquisition, resettlement or economic displacement. |
| 14 | Poverty | | Because of no land acquisition and resettlement, activities that have a negative impact on people with poor class are not expected. |

| No. | Impact item | Evaluation | Reason for evaluation |
|---|---|---|---|
| | | CS | |
| 15 | Indigenous and ethnic people | | Because of no land acquisition and resettlement, activities that have a negative impact on indigenous and ethnic people are not expected. |
| 16 | Local economy such as employment and livelihood, etc. | | No activity that will impact on local economy and livelihood is expected. |
| 17 | Land use and utilization of local resources | ✓ | If the need for soil and crushed stones exceeds the expectations, the excavation range may be expanded and Land use and utilization of local resources may be affected. |
| 18 | Water use and its rights | ✓ | If the need for soil and crushed stones exceeds the expectations, the excavation range may be expanded and water use and its rights may be affected. |
| 19 | Existing social infrastructure and services | ✓ | Existing roads, schools, hospitals, and community centers may be temporarily affected due to frequent dump truck traffic. |
| 20 | Social institutions such as social infrastructure and local decision - making institutions | | No activity that will impact social institutions is expected. |
| 21 | Maldistribution of benefit and damage | | No activity that will impact distribution of benefit and damage is expected. |
| 22 | Local conflict of interest | ✓ | If the need for soil and crushed stones exceeds the expectations, the excavation range may be expanded and local conflict may occur between the owner and residents. |
| 23 | Cultural Heritage | ✓ | Some negative impacts may occur if there is a cultural heritage near the project area. |
| 24 | Landscape | ✓ | If the need for soil and crushed stones exceeds the expectations, the excavation range may be expanded and the landscape may be affected. |
| 25 | Gender | | No activity that will impact on gender is expected. |
| 26 | Children's right | | No activity that will impact on children's rights is expected. |
| 27 | Health (Infectious diseases such as HIV/AIDS, etc.) | | No activity that will impact on health is expected. |
| 28 | Labor environment including labor safety | ✓ | It is necessary to secure an appropriate working environment following relevant laws. |
| Others | | | |
| 29 | Accidents | ✓ | Traffic accidents may increase because of construction vehicles. |
| 30 | Cross border impact and climate change | | Cross-border impacts and impact on climate change is not expected. |

Note: ✓: Items to be assessed, CS: Construction Stage

Source: JST

### 14.5.2 Method of Environmental baseline Survey and Analysis

The TOR of the Environmental and Social Consideration Survey (EIA survey) and the survey points and area are shown below. Since the construction of the project has already been started on the partial section, the status of land acquisition, EMP, EMoP, and project implementation shall be confirmed by checking the monthly report of the section as retroactive confirmation items.

Since a survey in the dry season by PMRC has already been conducted in 2020, an additional survey for each assessment item will be conducted in the rainy season. Additionally, an interview survey for local

people was conducted to understand their socio-economic status that were not included in the same types of survey conducted in 2020 such as Child labor, Gender Equity, Ecosystem services etc. along the Corridors. The target will be 10 people per station, 240 people in total.

**Table 14-18: Content and analysis method of the baseline survey**

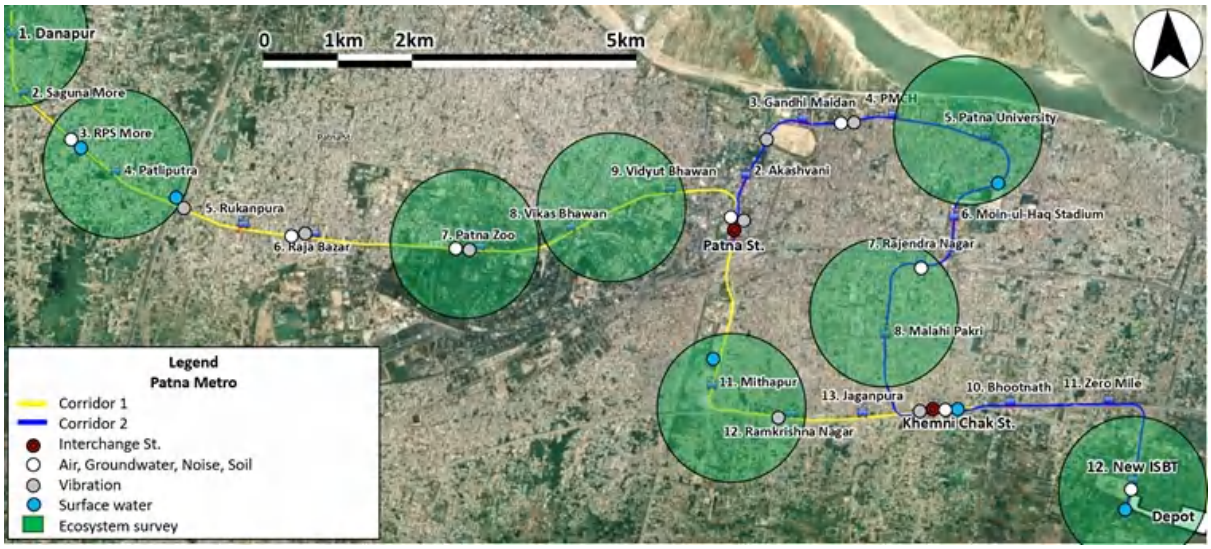
| No. | Impacted Item | Sampling/Site Measurement Survey | Analysis and Method |
|---|---|---|---|
| **Pollution** | | | |
| 1 | Air pollution | I. Field survey<br>(1) 8 points in total for all alignment of Corridor 1 and 2<br>(2) Air (prevention and control of pollution) Act, 1981<br>(3) Item: $SO_2$, CO, $NO_2$, $O_3$, $PM_{10}$, $PM_{2.5}$, 24hrs<br>(4) Frequency: Once<br>Note) Since the survey in dry season has already been conducted, a survey in rainy season will be conducted.<br>II. Impact during construction | I. Comparison of survey results with existing survey results and standard values.<br>II. Confirm the contents of construction, method, period, area, type of construction machine, its operating position and period, number of construction vehicles, its period, and running route. |
| 2 | Water pollution | I. Field survey<br>**Surface Water**<br>(1) 6 points at canals, ponds, rivers along the alignment of Corridor 1 and 2<br>(2) IS 10500 : 2012, DRINKING WATER — SPECIFICATION<br>(3) Item: Colour, Odor, Turbidity, pH at 25°C, Electrical Conductivity, Total Hardness as $CaCO_3$, Chloride as Cl, Total Iron as Fe, Total Dissolved Solids, Sulphates as $SO_4$, Nitrates as $NO_3$, Lead as Pb, Copper as Cu, Manganese as Mn, Mercury as Hg, Cadmium as Cd, Zinc as Zn, Chromium as Cr+6, Total Alkalinity as $CaCO_3$, Calcium as Ca, Magnesium as Mg, Sodium, Potassium, Dissolve Oxygen, BOD, COD<br>(4) Frequency: Once<br>Note) Secondary data collection, if any<br>**Ground Water**<br>(1) 8 points in total for all alignment of Corridor 1 and 2<br>(2) IS 10500 : 2012, DRINKING WATER — SPECIFICATION<br>(3) Item: Colour, Odor, Taste, Turbidity, pH at 25°C, Total Hardness as $CaCO_3$, Chloride as Cl, Total Iron as Fe, Total Dissolved Solids, Sulphates as $SO_4$, Nitrates as $NO_3$, Fluorides as F, Lead as Pb, Copper as Cu, Manganese as Mn, Phenolic Compound as $C_6H_5OH$, Mercury as Hg, Cadmium as Cd, Arsenic as, Cyanide as Cn, Zinc as Zn, Detergent as MBAS, Chromium as $Cr^{+6}$, Total Alkalinity as $CaCO_3$, Aluminum as Al, Boron as B, Coliform, E-Coli<br>(4) Frequency: Once<br>Note) Since the survey in dry season has already been conducted, a survey in rainy season will be conducted.<br>II. Impact during construction | I. Comparison of survey results with existing survey results and standard values.<br>II. Confirm the contents of construction, method, period, area, type of construction machine, its operating position and period, number of construction vehicles, its period, and running route. |

| No. | Impacted Item | Sampling/Site Measurement Survey | Analysis and Method |
|---|---|---|---|
| 3 | Waste | Construction waste disposal method<br>Note) A construction waste disposal site currently in use has been identified. | - Information collection on registered construction waste disposal sites along Corridor 1 and 2 or conducted field surveys in some cases.<br>- Quantitative prediction |
| 4 | Soil contamination | I. Field survey<br>(1) 8 points in total for all alignment of Corridor 1 and 2<br>(2) Item: pH, Electrical Conductivity, Cadmium as Cd, Lead as Pb, Mercury as Hg, Cyanide as Cn, Chromium as $Cr_6^+$, Arsenic as<br>(3) Frequency: Once<br>Note) Since the survey in dry season has already been conducted, a survey in rainy season will be conducted.<br>II. Impact during Patna Metro operation | I. Comparison of survey results with existing survey results and standard values.<br>II. Hearing with PMRCL |
| 5 | Noise and Vibration | I. Field survey<br>**1. Noise**<br>(1) 8 points in total for all alignment of Corridor 1 and 2<br>(2) Noise pollution (regulation and control) rules, 2000<br>(3) Item: LAmax, LAmin, LAeq, 24hrs<br>(4) Frequency: Once<br>**2. Vibration**<br>(1) 8 points in total for all alignment of Corridor 1 and 2<br>(2) Item: Lv: Vibration as velocity<br>(3) Frequency: Once<br>Note) Add the sampling points adjacent to the sensitive buildings such as school, hospital and heritage, if existed in and around the project site. Since the survey in dry season has already been conducted, a survey in rainy season will be conducted.<br>II. Noise/vibration level during construction and operation at the representative section<br>III. Impact during construction | I. Comparison of survey results with existing survey results and standard values.<br>II. Noise: Quantitative prediction (Traffic noise at the road boundaries of typical elevated sections and at sensitive points/ LAeq dB(A))<br>Vibration: Quantitative prediction (Traffic vibration at the road boundaries of typical underground sections and at sensitive points/ Lv dB)<br>III. Confirm the contents of construction, method, period, area, type of construction machine, its operating position and period, number of construction vehicles, its period, and running route. |
| 6 | Ground subsidence | Impact during construction | Utilization of existing topographic survey results and underground survey results, and hearings with PMRCL (including construction details of the depot and countermeasures against the impact on a surrounding river) |
| 7 | Offensive odor | Impact during construction and during Patna Metro operation | Information collection of odor that are expected to generate from base camps, stations and a depot |
| **Natural environment** | | | |
| 8 | Protected Area | Impact during construction and during Patna Metro operation | Collecting information (including bird list, if possible) on the protected area and confirming the content of discussions with PMRCL and park authority |

| No. | Impacted Item | Sampling/Site Measurement Survey | Analysis and Method |
|---|---|---|---|
| 9 | Ecosystem | I. Field survey<br>(1) Site observation: 8 points in total along Corridor 1 and 2 including Danapur Cantonment Key Biodiversity Area (KBA), and Sanjay Gandhi Biological Park<br>(2) Target: Affected flora and fauna by the construction<br>(3) Item<br>Terrestrial flora and fauna: Species name, Scientific name and Distribution including categorization of IUCN Red list and their photos for identification.<br>Especially for current condition of breeding, nesting of below species.<br>Asian Openbill (*Anastomus oscitans*), Painted Stork (*Mycteria leucocephala*)<br>(4) Frequency: One time<br>Note) Interview for Expert, Professor, if any judging whether it is a "critical habitat" in the JICA guidelines depending on the habitat status of the species.<br>II. Confirmation of land use, Ecosystem distribution and Ecosystem services | I. Information collection through existing literature survey and field survey<br>II. Information collection through existing literature and interviews with experts, etc. as necessary |
| 10 | Hydrology | I. Past flood history survey<br>II. Impact during construction | I. Information collation<br>II. Utilization of existing topographic survey results and underground survey results, and hearings with PMRCL |
| 11 | Topography and geology | Impact during construction | Utilization of existing topographic survey results and underground survey results, and hearings with PMRCL |
| **Social environment** | | | |
| 12 | Land acquisition / resettlement | Refer to Social Impact assessment (SIA) survey (Chapter 15) | |
| 13 | Poverty | | |
| 14 | Indigenous and ethnic people | | |
| 15 | Local economy such as employment and livelihood, etc. | | |
| 16 | Land use and utilization of local resources | Confirmation of land use and utilization of local resources | Utilization of existing data, and Interview survey results |
| 17 | Water use and its rights | Confirmation of water usage situation of local people | Utilization of existing data, and Interview survey results |
| 18 | Existing social infrastructures and services | I. Field survey<br>(1) Site measurement: A range of 100 m width along the Corridors<br>(2) Item: Distribution of hospital, school, religious place, community center, etc.<br>(3) Frequency: One time<br>II. Distribution of underground facility | I. Utilization of existing data, site inspection and interview survey results<br>II. Existing CAD data |
| 19 | Maldistribution of benefit and damage | I. Confirmation of prohibition of road crossing and setting of the detour route.<br>II. Opinion collection from companies of route buses and union of three wheelers | Utilization of existing data, SIA survey results and Interview survey results |

| No. | Impacted Item | Sampling/Site Measurement Survey | Analysis and Method |
|---|---|---|---|
| 20 | Local conflict of interest | Impact on local conflict of interest | Utilization of existing data, and Interview survey results |
| 21 | Cultural heritage | Cultural and historical heritage in the vicinity of the Corridors | Utilization of existing data, and Interview survey results |
| 22 | Landscape | I. Site measurement: Survey of main view spot (commanding Viaduct, Railway track, Station buildings)<br>II. Collection of similar cases | I. Photo shoot<br>II. Utilization of existing data |
| 23 | Gender | Refer to Social Impact assessment (SIA) survey | |
| 24 | Children's rights | Impact on children's rights | - Confirmation of domestic related laws<br>- Whether there is any child labor around the project site |
| 25 | Health (Infectious diseases such as HIV/AIDS, etc.) | I. Infectious disease rate in the vicinity of the Corridors<br>II. Implementing agency of related activity | Utilization of existing data, and Interview survey results |
| 26 | Labor environment including labor safety | I. Confirmation of related domestic laws and international standards<br>II. Confirmation of work safety measures at the construction site | I. Information collection<br>II. Site inspection and hearing |
| **Others** | | | |
| 27 | Accidents | Number of traffic accidents along the Corridors and reasons for the accidents | - Utilization of existing data , and site inspection<br>- Collection of traffic accident data from police station, if any |
| 28 | Cross border impact and climate change | I. Calculation of the amount of $CO_2$<br>- During operation<br>- Reduction amount from road traffic compared to when the project was not implemented<br>II. Interview survey with Attachment 10&11, Secondary data collection | I. Estimation result of future traffic volume, JICA Climate FIT<br>II. Data collection, and hearing with PMRCL |

Source: JST




Source: JST based on Google Earth

**Figure 14-20: EIA Survey points and Areas in rainy season**

## 14.6 The result of the EIA survey

PMRCL has already conducted a survey on various impact items for environmental and social considerations, and summarized the survey results in the Environmental Impact Assessment (hereinafter referred to as "EIA") Report and Social Impact Assessment (hereinafter referred to as "SIA") Report in July 2020. Therefore, the results excerpts from those reports are mentioned as the survey result in dry season. The survey points for each impact item are as follows, and the results are shown in the below chapter alongside the results conducted in rainy season, that is July 2022.




Source: JST based on Google Earth and Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Figure 14-21: Survey Points conducted in dry season**

### 14.6.1 Air Pollution

#### (1) Survey

The air quality surveys were conducted by WHO in 2016 and 2018 in Patna, and especially the value of $PM_{2.5}$ was ranked third (149 mg/m$^3$) and fifth (144 mg/m$^3$) respectively from the bottom among 3,000 cities in the world. Therefore, it can be said that the air quality in Patna has an extremely poor condition[39]. The air quality survey for the project was conducted in January 2020 during the dry season, and in July 2022 during the rainy season, and the results are as follows. The values of $PM_{10}$ and $PM_{2.5}$ exceeded the environmental standard of India at all points in both seasons, and some of the $PM_{2.5}$ values are more than the WHO's values in the dry season. In addition, since the value of $SO_x$ also exceeded the standard at 5 points in the dry season, an urgent countermeasure shall be needed to improve the air quality environment. Main factors of air pollution include rapid population growth in India, traditional cooking styles, thermal power plant operations, and soot/smoke due to brick production. A power plant is located on the southern area of Patna Junction, but it was closed in 1984, and there could be no large-scale pollution source facility along the Corridors. Standard values for general air quality in India are stipulated in Central Pollution Control Board (CPCB) Notification dated 18th Nov. 2009.

[39] Air quality database 2016 and 2018, WHO

**Table 14-19: Survey Result in dry season**

| Location | $PM_{10}$ | $PM_{2.5}$ | CO | $NO_2$ | $SO_2$ | $O_3$ |
|---|---|---|---|---|---|---|
| 1. Danapur | **124** | **96** | 0.77 | 11.3 | 73.2 | - |
| 2. Raja Bazar | **137** | **101** | 0.83 | 11.9 | 79.8 | - |
| 3. Patna Zoo | **146** | **113** | 1.23 | 13.8 | **87.4** | - |
| 4. Patna Junction | **259** | **156** | 1.39 | 17.2 | **119.3** | - |
| 5. Mithapur | **217** | **143** | 1.27 | 15.4 | **105.3** | - |
| 6. PMCH | **216** | **137** | 1.19 | 9.7 | 57.1 | - |
| 7. University | **253** | **171** | 1.14 | 10.4 | 64.5 | - |
| 8. Khemni Chak | **312** | **168** | 1.41 | 15.6 | **94.1** | - |
| 9. New ISBT | **281** | **141** | 1.37 | 14.2 | **88.2** | - |
| CPCB 2009 | 100 (24 hrs) | 60 (24 hrs) | 4.0 (1 hr) | 80 (24 hrs) | 80 (24 hrs) | 180 (24 hrs) |
| IFC | 150 (24 hrs) | 75 (24 hrs) | - | 200 (1 hr) | 125 (24 hrs) | 160 (8 hrs) |

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC, Air (Prevention and Control of Pollution) Act, 1981/ Environmental, Health, and Safety Guidelines, IFC

**Table 14-20: Survey Result in rainy season**

| Location | $PM_{10}$ | $PM_{2.5}$ | CO | $NO_2$ | $SO_2$ | $O_3$ |
|---|---|---|---|---|---|---|
| 1. R.P.S More | **169.84** | **81.79** | 0.57 | 16.24 | 6.84 | 23.54 |
| 2. Raja Bazar | **178.23** | **89.23** | 0.63 | 19.52 | 9.87 | 17.69 |
| 3. Patna Zoo | **157.49** | **96.21** | 0.68 | 17.36 | 6.54 | 22.08 |
| 4. Patna Junction | **186.47** | **79.36** | 0.71 | 16.53 | 7.36 | 18.69 |
| 5. Gandhi Maidan | **129.54** | **76.52** | 0.69 | 13.57 | 5.69 | 19.84 |
| 6. Rajendra Nagar | **201.48** | **71.25** | 0.70 | 15.47 | 8.42 | 18.66 |
| 7. Khemni Chak | **196.32** | **91.47** | 0.73 | 20.13 | 7.32 | 21.38 |
| 8. New ISBT | **195.24** | **84.78** | 0.86 | 18.74 | 9.51 | 19.74 |
| CPCB 2009 | 100 (24 hrs) | 60 (24 hrs) | 4.0 (1 hr) | 80 (24 hrs) | 80 (24 hrs) | 180 (24 hrs) |
| IFC | 150 (24 hrs) | 75 (24 hrs) | - | 200 (1 hr) | 125 (24 hrs) | 160 (8 hrs) |

Source: JST, Central Pollution Control Board Notification dated 18th Nov. 2009/ Environmental, Health, and Safety Guidelines, IFC

### 1) Particulate Matters ($PM_{10}$ and $PM_{2.5}$)

$PM_{10}$ and $PM_{2.5}$ refer to particulate matter 10 micrometers or less in diameter and particulate matter $_{2.5}$ micrometers or less in diameter, respectively. $PM_{2.5}$ is generally described as fine particles. The major components of PMs are sulfate, nitrates, ammonia, sodium chloride, black carbon, mineral dust, and water. It consists of a complex mixture of solid and liquid particles of organic and inorganic substances suspended in the air. Dust emission level was checked by measuring the concentration level of $PM_{10}$ and $PM_{2.5}$ for 24 hours. Values of $PM_{10}$ at all points are found that exceeded the Standard of India of 100 $\mu g/m^3$. During the dry season, many points exceeded twice the standard value, especially at Khemni Chak, where they were more than three times the standard value. Even during the rainy season, the values

at Rajendra Nagar, Khemni Chak and New ISBT were particularly high, and were more than double the standard value or close to it. Also, all values of $PM_{2.5}$ exceeded the standard values. During the dry season, many points exceeded twice the standard value.

### 2) Carbon Monoxide (CO)

Carbon monoxide is a poisonous gas that has no taste or smell. It is mainly generated from incomplete combustion of carbon, i.e., when there is not enough supply of oxygen to produce carbon dioxide ($CO_2$), only half of the oxygen is combined with carbon, and carbon monoxide is formed. It is also formed from the combustion of fossil fuels, motor vehicle exhausts, and industrial fumes. When carbon monoxide is inhaled, it enters the bloodstream of the body and inhibits the carriage of oxygen and the lack of oxygen causes the function of body cells and tissues to fail. Excess inhalation of carbon monoxide can even lead to death. In 1 hour of measured values of CO level concentration, all concentrations were within the standard of India of 4.0 $mg/m^3$.

### 3) Nitrogen Dioxide ($NO_2$)

Nitric oxide (NO) and nitrogen dioxide ($NO_2$) are the two principal nitrogen oxides. It can be generated from the operation and maintenance of vehicles and on-site power generation facilities. The quantity of nitrogen oxides depends on the available nitrogen and oxygen concentration, reaction time, and temperature. It can cause bronchitis and edema in the lungs.

The concentration of ambient $NO_2$ levels was measured for 24 hours in the survey. The 24 hours concentration at Patna Junction where is the highest point during the dry season was 17.2$\mu g/m^3$, and it at Khemni Chak where is the highest point during the rainy season was 20.13 $\mu g/m^3$. All measurements were found to be lower than 80 $\mu g/m^3$, the standard value of India.

### 4) Sulfur Dioxide ($SO_2$)

Sulfur dioxide is generated from the combustion of fuel such as oil, and as a by-product of some chemical products. On-road and off-road vehicles can also be emission sources of $SO_2$ which may cause respiratory diseases and irritation of the throat and eyes. During the dry season, five of the nine sites exceeded the standard, and values were generally high. On the other hand, during the rainy season, the values were not only below the Indian standard of 80 $\mu g/m^3$ at all points, but were also very low compared to values during the dry season.

### 5) Ozone ($O_3$)

Ground-level ozone is not emitted directly into the air. It is created from chemical reactions between oxides of nitrogen and volatile organic compounds in the presence of sunlight. Gas exhausted from industrial facilities, motor vehicles, internal combustion engines, especially automobiles, and coal fire power plants is the main sources of nitrogen oxides and VOCs. Besides, damaging vegetation and the ecosystem, ground-level ozone may cause a variety of health issues such as lung damage and irritation along the respiratory tract when inhaled. The concentration of ozone was recorded for 1 hour at each point. In comparing the resultant average concentrations with the standard of India, it can be seen that all the values are under the standard value of 180 $\mu g/m^3$.

### (2) Prediction

A quantitative prediction was expected, but a confident evaluation of the prediction result could not be made due to underdevelopment of general environmental data in India, including wind direction and speed, a flux of insolation, atmospheric radiant quantity, cloudiness, and atmospheric stability. Therefore, a qualitative prediction was implemented.

#### 1) Construction phase

Based on the current status of air quality in Patna city, the construction heavy machines and dump trucks may cause further traffic congestion and deterioration of atmospheric environment. However, this adverse impact is not severe because of the following reasons:

- Most of the earthworks is limited only to excavation at pillars in the elevated section
- Since most of the underground station will be constructed under arterial roads or under the land along narrow roads, the deterioration of traffic congestion due to the operation of heavy machinery is limited.
- Proper work schedules will be developed so that the construction equipment will not be concentrated at a certain point for a long time.

In addition to the above, mitigation measures during construction such as an adaptation of low-exhaust heavy machines and dump trucks, unnecessary idle running of the engine, the periodical water spray, and installation of high fence should be taken not to deteriorate the quality.

#### 2) Operation phase

Since the number of registered vehicles in Patna city is anticipated to increase as the population in the city continues to grow, the traffic volume along Patna Metro will also increase. On the other hand, it is expected that the traffic volume along Patna Metro declines temporarily after 2025 because a transportation shift from private cars and buses to Patna Metro is expected. Additionally, some road improvement projects such as the construction of high standard road construction and flyover are planned along Patna Metro to mitigate the current traffic congestion. Therefore, it can be said that the air quality in Patna city will slightly improve. Besides, since no emission gas generates from the Patna Metro, and the emission coefficient for NOx and SOx will be reduced by the renewal of the vehicle, it is anticipated that the air quality in Patna city will be improved accordingly.

## 14.6.2 Water Pollution

### (1) Survey

Ground water quality survey along the alignment, was carried out in January 2020 during the dry season, and in July 2022 during the rainy season. The location of ground water quality sampling and a summary of the results are shown in the below table. Since the values of Fluorides and Nitrate exceeded the environmental standard of India at all points during the dry season, and the values of Iron exceeded the standard at some points during the rainy season, the water quality environment can be said to be poor. However there is a minor impact on the local people because all the respondents have told that they use

water supplied through tap water provided by Patna Municipal Corporation (PMC) for daily usage and there is no use of nearby river water or lake water for fishing, fishery, washing for laundries and dishes etc.in daily life according to the interview survey conducted in July 2022. There are no large-scale pollution source facilities in the surrounding area. Standard values for drinking water quality in India are stipulated in IS 10500: 2012, Indian Standard, Drinking Water - Specification. For surface water quality measurement, in comparing against the Indian standards values, values of all items were lower than Indian surface water requirements at all points. Standard values for surface water quality in India are stipulated in General Standards for Discharge of Environmental Pollutants in Environment (Protection) Rules, 1986.

### (2) Prediction

Regarding the treatment of domestic wastewater and industrial-related drainage in Patna city, it is discharged untreated into the drainage channel with rainwater and flows into rivers and lakes in the city. In the rainy season, the rainwater mixed with sewage overflows into the city resulting in the deterioration of the sanitary environment. Additionally, turbid water may be generated from the excavation work for the construction of Patna Metro piers and underground stations due to the high groundwater level, so further deterioration of water quality may occur. However, this impact is not severe because of the following reasons:

- Earthwork for elevated sections is limited to excavation for pier construction
- Insertion of a diaphragm wall at every underground station site to avoid phreatic fluctuation and deterioration of ground water quality

Adding to the above, mitigation measures such as the installation of settle basins at every construction site and the wastewater treatment system at the construction yard should be installed not to deteriorate the water quality. In the operation phase, there is a possibility of discharged organic wastewater from the toilet installed at every station and depot, but the wastewater treatment system at every station and a depot should be also installed to keep the water quality. In addition, “all sewage treatment plants (SYPs) construction work” in Patna City area is scheduled to be completed in 2022-2023[40] as a Namami Gange Programme[41], by which future water quality improvement of rivers and lakes is expected.

[40] https://www.constructionworld.in/urban-infrastructure/wastewater-and-sewage-treatment/patna---s-sewerage-projects-under-namami-gange-to-be-completed-by-2023/33939

[41] Integrated Conservation Mission, approved as "Flagship Programme" by the Union Government of India in June 2014 with budget outlay of Rs.20,000 crore.

**Table 14-21: Result of Ground water quality in dry season (1)**

| Item | Unit | Danapur | Raja Bazar | Patna Zoo | Mithapur | Permissile Limits (IS 10500:2012) | WHO (drinking water) |
|---|---|---|---|---|---|---|---|
| Colour | Hazen | Colourless | Colourless | Colourless | Colourless | 5 (15) Max | 15 Pt-unit |
| Odor | | Unobjectionable | Unobjectionable | Unobjectionable | Unobjectionable | Agreeable | Acceptable |
| Taste | | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Acceptable |
| Turbidity | N.T.U | 3.5 | 2.3 | 3.7 | 2.6 | 1 (5) Max | Less than 5 N.T.U |
| pH at 25ºC | | 7.86 | 7.74 | 7.82 | 7.72 | 6.5-8.5 Max | - |
| Total Hardness as $CaCO_3$ | mg/l | 246 | 258 | 217 | 182 | 200 (600) Max | |
| Chloride as Cl | mg/l | 89 | 67 | 92 | 87 | 250 (1000) Max | - |
| Total Iron as Fe | mg/l | 0.05 | 0.09 | 0.17 | 0.11 | 0.3 Max | 0.3 |
| Total Dissolved Solids | mg/l | 1497 | 1388 | 1635 | 1402 | 500 (2000) Max | |
| Sulphates as $SO_4$ | mg/l | 124 | 129 | 105 | 114 | 200 (400) Max | 250 |
| Nitrates as $NO_3$ | mg/l | **51** | **57** | **58.1** | **51** | 45 Max | 50 |
| Fluorides as F | mg/l | **3.28** | **2.74** | **3.87** | **3.31** | 1.0 (1.5) Max | 1.5 |
| Lead as Pb | mg/l | BDL | BDL | BDL | BDL | 0.01 Max | 0.01 |
| Copper as Cu | mg/l | BDL | BDL | BDL | BDL | 0.05 (1.5) Max | 1.0 |
| Manganese as Mn | mg/l | BDL | BDL | BDL | BDL | 0.1 (0.3) Max | 0.1 |
| Phenolic Compound as $C_6H_5OH$ | mg/l | BDL | BDL | BDL | BDL | 0.001 (0.002) Max | - |
| Mercury as Hg | mg/l | BDL | BDL | BDL | BDL | 0.001 | 0.001 |
| Cadmium as Cd | mg/l | BDL | BDL | BDL | BDL | 0.003 | 0.003 |
| Selenium as Se | mg/l | BDL | BDL | BDL | BDL | 0.01 | 0.01 |
| Arsenic as As | mg/l | BDL | BDL | BDL | BDL | 0.01 (0.05) | 0.01 |
| Cyanide as Cn | mg/l | BDL | BDL | BDL | BDL | 0.05 | 0.07 |
| Zinc as Zn | mg/l | 2.07 | 1.84 | 1.04 | 1.65 | 5 (15) | - |
| Detergent as MBAS | mg/l | BDL | BDL | BDL | BDL | 0.02 (1.0) | - |
| Chromium as $Cr^{+6}$ | mg/l | BDL | BDL | BDL | BDL | 0.05 | 0.05 |
| Total Alkalinity as $CaCO_3$ | mg/l | 127 | 124 | 146 | 138 | 200 (600) | - |
| Aluminum as Al | mg/l | BDL | BDL | BDL | BDL | 0.03 (0.2) | - |
| Boron as B | mg/l | BDL | BDL | BDL | BDL | 0.5 (1.0) | 0.5 |
| Coliform | MPN/100ml | Nil | Nil | Nil | Nil | - | - |
| E-Coli | MPN/100ml | Negative | Negative | Negative | Negative | - | 0 |

*BDL: Below Detection Limit

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC, IS 10500 : 2012 Indian Standard DRINKING WATER — SPECIFICATION / Guidelines for Drinking-water Quality, (WHO)

**Table 14-22: Result of Ground water quality in dry season (2)**

| Item | Unit | Patna Junction | PMCH | Patna Univ. | Khemni Chak | Permissile Limits (IS 10500:2012) | WHO (drinking water) |
|---|---|---|---|---|---|---|---|
| Colour | Hazen | Colourless | Colourless | Colourless | Colourless | 5 (15) Max | 15 Pt-unit |
| Odor | | Unobjectionable | Unobjectionable | Unobjectionable | Unobjectionable | Agreeable | Acceptable |
| Taste | | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Acceptable |
| Turbidity | N.T.U | 4.1 | 3.6 | 3.2 | 2.7 | 1 (5) Max | Less than 5 N.T.U |
| pH at 25ºC | | 7.65 | 7.75 | 7.69 | 7.83 | 6.5-8.5 Max | - |
| Total Hardness as $CaCO_3$ | mg/l | 315 | 224 | 216 | 253 | 200 (600) Max | |
| Chloride as Cl | mg/l | 142 | 94 | 73 | 129 | 250 (1000) Max | - |
| Total Iron as Fe | mg/l | 0.28 | 0.16 | 0.12 | 0.27 | 0.3 Max | 0.3 |
| Total Dissolved Solids | mg/l | **2147** | 1671 | 1237 | 1924 | 500 (2000) Max | |
| Sulphates as $SO_4$ | mg/l | 168 | 117 | 91 | 108 | 200 (400) Max | 250 |
| Nitrates as $NO_3$ | mg/l | **76** | **78** | **49** | **71** | 45 Max | 50 |
| Fluorides as F | mg/l | **2.58** | **2.97** | **2.69** | **4.32** | 1.0 (1.5) Max | 1.5 |
| Lead as Pb | mg/l | BDL | BDL | BDL | BDL | 0.01 Max | 0.01 |
| Copper as Cu | mg/l | BDL | BDL | BDL | BDL | 0.05 (1.5) Max | 1.0 |
| Manganese as Mn | mg/l | BDL | BDL | BDL | BDL | 0.1 (0.3) Max | 0.1 |
| Phenolic Compound as $C_6H_5OH$ | mg/l | BDL | BDL | BDL | BDL | 0.001 (0.002) Max | - |
| Mercury as Hg | mg/l | BDL | BDL | BDL | BDL | 0.001 | 0.001 |
| Cadmium as Cd | mg/l | BDL | BDL | BDL | BDL | 0.003 | 0.003 |
| Selenium as Se | mg/l | BDL | BDL | BDL | BDL | 0.01 | 0.01 |
| Arsenic as As | mg/l | BDL | BDL | BDL | BDL | 0.01 (0.05) | 0.01 |
| Cyanide as Cn | mg/l | BDL | BDL | BDL | BDL | 0.05 | 0.07 |
| Zinc as Zn | mg/l | 2.31 | 2.41 | 1.09 | 1.61 | 5 (15) | - |
| Detergent as MBAS | mg/l | BDL | BDL | BDL | BDL | 0.02 (1.0) | - |
| Chromium as $Cr^{+6}$ | mg/l | BDL | BDL | BDL | BDL | 0.05 | 0.05 |
| Total Alkalinity as $CaCO_3$ | mg/l | 159 | 163 | 135 | 156 | 200 (600) | - |
| Aluminum as Al | mg/l | BDL | BDL | BDL | BDL | 0.03 (0.2) | - |
| Boron as B | mg/l | BDL | BDL | BDL | BDL | 0.5 (1.0) | 0.5 |
| Coliform | MPN/100ml | Nil | Nil | Nil | Nil | - | - |
| E-Coli | MPN/100ml | Negative | Negative | Negative | Negative | - | 0 |

*BDL: Below Detection Limit

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC, IS 10500 : 2012 Indian Standard DRINKING WATER — SPECIFICATION / Guidelines for Drinking-water Quality, (WHO)

**Table 14-23: Result of Ground water quality in rainy season**

| Item | Unit | R.P.S. More | Raja Bazar | Patna Zoo | Patna Junction | Gandhi Maidan | Rajendra Nagar | Khemni Chak | New ISBT | Permissible Limits (IS 10500:2012) | WHO (Drinking Water) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Colour | Hazen | Colourless | Colourless | Colourless | Colourless | Colourless | Colourless | Colourless | Colourless | 5 (15) Max | 15 Pt-unit |
| Odour | - | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Acceptable |
| Taste | - | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Acceptable |
| Turbidity | NTU | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 1 (5) Max | Less than 5 N.T.U |
| pH at 25°C | - | 7.45 | 7.40 | 8.02 | 7.1 | 7.4 | 7.69 | 7.5 | 7.55 | 6.5-8.5 Max | -- |
| Total Hardness as $CaCO_3$ | mg/L | 212.85 | 207.9 | 123.75 | 287.1 | 212.85 | 247.5 | 292.05 | 222.75 | 200 (600) Max | |
| Chloride as Cl | mg/L | 57 | 28.5 | 16.63 | 28.5 | 49.88 | 30.88 | 49.88 | 57 | 250 (1000) Max | - |
| Iron as Fe | mg/L | 0.16 | 0.21 | **0.35** | 0.24 | 0.26 | **0.31** | **0.41** | 0.21 | 0.3 Max | 0.3 |
| Total Dissolved Solids | mg/L | 310 | 255 | 165 | 320 | 248 | 275 | 359 | 261 | 500 (2000) Max | |
| Sulphates as $SO_4$ | mg/L | 19.97 | 16.09 | 9.77 | 16.23 | 19.83 | 15.95 | 21.69 | 24.42 | 200 (400) Max | 250 |
| Nitrates as $NO_3$ | mg/L | 4.56 | 3.27 | 1.02 | 5.24 | 4.15 | 5.44 | 7.21 | 4.15 | 45 Max | 50 |
| Fluoride as F | Mg/L | 0.23 | 0.21 | 0.19 | 0.24 | 0.2 | 0.22 | 0.25 | 0.2 | 1.0 (1.5) Max | 1.5 |
| Lead as Pb | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.01 Max | 0.01 |
| Copper as Cu | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.05 (1.5) Max | 1.0 |
| Manganese as Mn | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.1 (0.3) Max | 0.1 |
| Phenolic Compound as $C_6H_5OH$ | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.001 (0.002) Max | - |
| Mercury as Hg | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.001 | 0.001 |
| Cadmium as Cd | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.003 | 0.003 |
| Total Arsenic as | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.01 (0.05) | 0.01 |
| Cyanide as Cn | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.05 | 0.07 |
| Zinc as Zn | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 5 (15) | - |
| Deergent as MBAS | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.02 (1.0) | - |
| Hexavalent Chromium as $Cr^{6+}$ | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.05 | 0.05 |
| Total Alkalinity as $CaCO_3$ | mg/L | 138.8 | 115.04 | 92.5 | 97.1 | 60.1 | 101.8 | 111 | 134.1 | 200 (600) | - |
| Aluminium as Al | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.03 (0.2) | - |
| Boron as B | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | BDL | BDL | 0.5 (1.0) | 0.5 |
| Coliform | MPN/100ml | Nil | Nil | Nil | Nil | Nil | Nil | Nil | Nil | - | - |
| E-Coli | MPN/100ml | Negative | Negative | Negative | Negative | Negative | Negative | Negative | Negative | - | 0 |

*BDL: Below Detection Limit

Source: JST, IS 10500:2012 Indian Standard DRINKING WATER-SPECIFICATION, Guidelines for Drinking-water Quality (WHO)

**Table 14-24: Result of Surface water quality in rainy season**

| Item | Unit | R.P.S. More | Patliputra | Mithapur | Moin UI Haq Stadium | Khemni Chak | New ISBT | WHO | India (Inland surface water) |
|---|---|---|---|---|---|---|---|---|---|
| Colour | Hazen | BDL | BDL | BDL | BDL | BDL | BDL | - | All efforts as far as practicable |
| Odour | - | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | Agreeable | - | |
| Turbidity | NTU | BDL | BDL | BDL | BDL | BDL | BDL | 5 | - |
| pH at 25°C | - | 7.46 | 7.65 | 7.15 | 7.17 | 7.15 | 6.95 | - | 5.5 - 9 |
| Total Hardness as $CaCO_3$ | mg/L | 99.00 | 108.90 | 148.50 | 153.45 | 59.40 | 247.50 | - | - |
| Chloride as Cl | mg/L | 16.63 | 40.38 | 19.00 | 95.01 | 21.38 | 76.00 | - | - |
| Iron as Fe | mg/L | 0.14 | 0.22 | 0.24 | 0.32 | 0.12 | 0.38 | - | 3.0 |
| Total Dissolved Solids | mg/L | 128.00 | 190.00 | 202.00 | 312.00 | 108.00 | 350.00 | - | - |
| Sulphates as $SO_4$ | mg/L | 5.46 | 8.48 | 5.60 | 27.73 | 6.08 | 20.69 | - | - |
| Nitrates as $NO_3$ | mg/L | 1.43 | 1.70 | 2.18 | 3.54 | 1.63 | 5.72 | - | 10 |
| Lead as Pb | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | - | 0.1 |
| Copper as Cu | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | - | 3.0 |
| Manganese as Mn | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | - | 2.0 |
| Mercury as Hg | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | - | 0.01 |
| Cadmium as Cd | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | - | 2.0 |
| Zinc as Zn | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | - | 5.0 |
| Hexavalent Chromium (as $Cr^{6+}$) | mg/L | BDL | BDL | BDL | BDL | BDL | BDL | - | 0.1 |
| Total Alkalinity as $CaCO_3$ | mg/L | 83.3 | 97.1 | 143.4 | 129.50 | 64.8 | 83.3 | - | - |
| Calcium as Ca | mg/L | 31.74 | 33.73 | 45.63 | 45.63 | 13.89 | 91.26 | - | - |
| Magnesium as Mg | mg/L | 4.77 | 5.97 | 8.36 | 9.57 | 6.00 | 4.70 | - | - |
| Sodium as Na | mg/L | 1.04 | 11.09 | 17.62 | 32.08 | 9.30 | 36.33 | - | - |
| Potassium as K | mg/L | 0.07 | 0.79 | 0.28 | 1.10 | 0.59 | 1.72 | - | - |
| Electrical Conductivity | ms/cm | 0.219 | 0.372 | 0.395 | 0.573 | 0.175 | 0.687 | - | - |
| Dissolved Oxygen | mg/L | 5.0 | 5.1 | 5.3 | 5.0 | 5.2 | 5.1 | - | - |
| Chemical Oxygen Demand (COD) | mg/L | 54.2 | 58.1 | 4.14 | 109.8 | 78.2 | 205.0 | 125 | 250 |
| Biological Oxygen Demand (BOD) | mg/L | 9.8 | 10.0 | BDL | 15.9 | 11.7 | 21.5 | 30 | 30 |

*BDL: Below Detection Limit

Source: JST, WHO, General Standards for Discharge of Environmental Pollutants Part-A: Effluents of Schedule – VI, The Environment (Protection) Rules, 1986

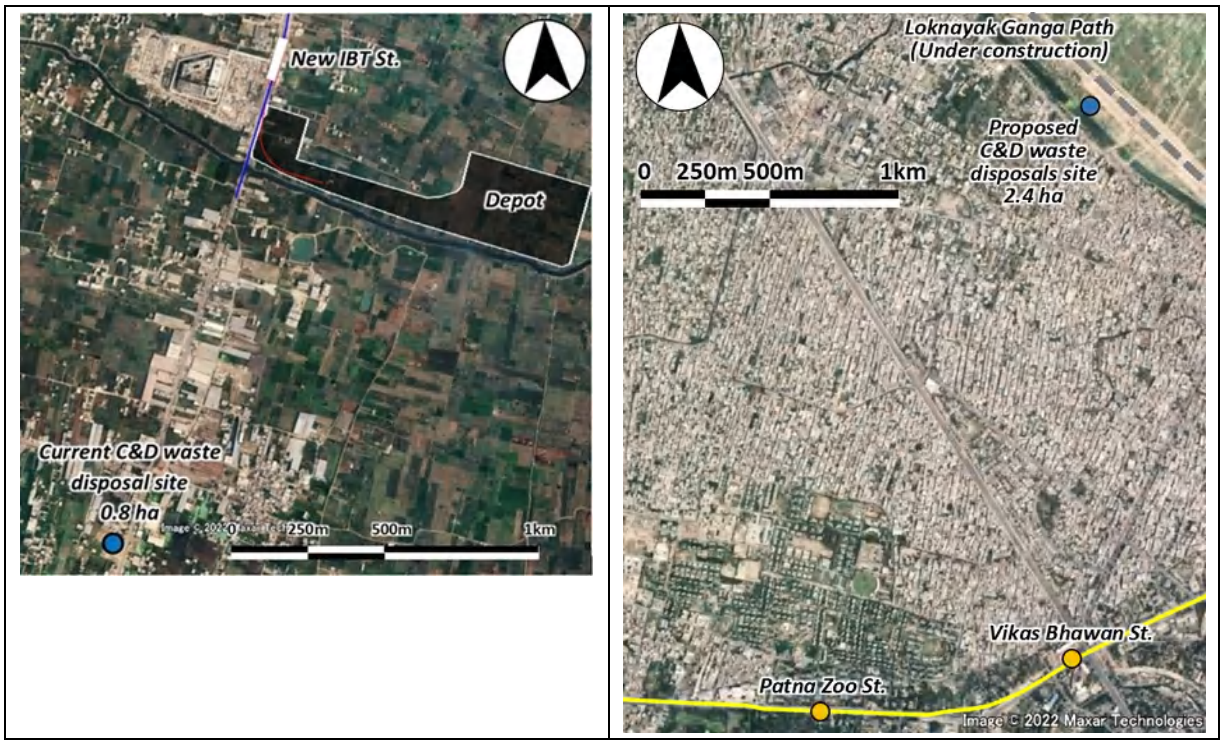
### 14.6.3 Waste

#### (1) General waste

In Patna City, regarding general waste, Door-to-Door Garbage Collection Service is implemented from 2018. In addition, there are currently four sewage treatment plants at Saidpur, Beur, Pahari and Karmali Chak, and construction of new sewage infrastructure is underway in the city since 2019.

#### (2) Construction and Demolition waste

Since construction works have already begun on a part of the elevated section of Patna Metro (between Khemni Chak St. and New ISBT St.), excavated soil has been generated due to the construction of piers. Currently, PMRCL transports the excavated soil to lowlands and swamps owned by the Government of Bihar and civilians for landfill, and carries the excavated soil to other candidate sites after the land is full. The candidate sites currently known are as shown in the satellite images below. As of October 2022, there is a large acceptable space for the excavated soil, construction and demolition waste.




Source: JST based on the information of PMRCL

**Figure 14-22: Acceptable Site for Construction Generated Soil and C &D Waste**

**Table 14-25: Excavated Soil Transportation, and Reuse and Storage of Crushed Stones**





**Excavated soil filling**



**Acceptable site for generated excavated soil**



**Storage of crushed stones**




**Reuse of crushed stones**

Source: PMRCL

## (3) Prediction

It is expected that land modification will be expected, at a depot area, at the pier construction sites, TBM section, ramp section, and every underground station sites, with a total of 2,232,568 $m^3$ of excavated soil. PMRCL plans to reuse an excavated soil generated at these sites as landfill for the embankment section of the expressway "Loknayak Ganga Path" under construction and the soil filling for a depot construction of Patna Metro, because a large amount of soil will be required for the construction of the depot. On the other hand, crushed stones that cannot be used for landfill are stored in the construction site with a cover to minimize the dust scattering, and will be reused as a base material for road pavement.

### 14.6.4 Soil contamination

#### (1) Survey

Soil sampling was conducted in January 2020, during the dry season, and in July 2022 during the dry season. The location of soil sampling points and results for each sample are shown in the tables below. As there are no reference standard values for soil in India, the results of some parameters were compared with Environmental Quality Standards for Soil in Japan as an international standard. In the dry season, the pH values of the soil are slightly alkaline, and the values of electric conductivity tend to be slightly higher than that of general soil. No other items were detected. In the rainy season, Lead (Pb), mercury (Hg), cadmium (Cd), and arsenic (As), which were not detected in the dry season, were detected, but the values were sufficiently small compared to Japanese standards. The pH values of the soil, except for R.P.S More and Raja Bazar, were alkaline, and the degree of alkalinity tends to be stronger than in the dry season. There could are no large-scale pollution source facilities in the surrounding area.

**Table 14-26: Result of Soil Quality in the dry season**

| Item | Unit | Danapur | Raja Bazar | Patna zoo | Patna St. | Japan |
|---|---|---|---|---|---|---|
| pH | - | 7.72 | 7.79 | 7.59 | 7.63 | - |
| Electrical Conductivity | mS/cm | 1.15 | 1.45 | 1.84 | 1.79 | - |
| Lead as Pb | ppm | ND | ND | ND | ND | 150 |
| Mercury as Hg | ppm | ND | ND | ND | ND | 15 |
| Cadmium as Cd | ppm | ND | ND | ND | ND | 45 |
| Arsenic as As | ppm | ND | ND | ND | ND | 150 |
| Cyanide as Cn | ppm | ND | ND | ND | ND | 50 |
| Chromium as Cr+6 | ppm | ND | ND | ND | ND | 250 |
| **Item** | **Unit** | **PMCH** | **Patna Univ.** | **Khemni Chak** | **New ISBT** | **Japan** |
| pH | - | 7.81 | 7.67 | 7.76 | 7.82 | - |
| Electrical Conductivity | mS/cm | 2.06 | 2.14 | 1.37 | 1.95 | - |
| Lead as Pb | ppm | ND | ND | ND | ND | 150 |
| Mercury as Hg | ppm | ND | ND | ND | ND | 15 |
| Cadmium as Cd | ppm | ND | ND | ND | ND | 45 |
| Arsenic as As | ppm | ND | ND | ND | ND | 150 |
| Cyanide as Cn | ppm | ND | ND | ND | ND | 50 |
| Chromium as Cr+6 | ppm | ND | ND | ND | ND | 250 |

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC, Environmental Quality Standards for Soil, Japan

**Table 14-27: Result of Soil Quality in the rainy season**

| Item | Unit | R.P.S. More | Raja Bazar | Patna zoo | Patna St. | Japan |
|---|---|---|---|---|---|---|
| pH | - | 4.81 | 5.57 | 8.09 | 7.85 | - |
| Electrical Conductivity | mS/cm | 0.616 | 0.153 | 0.148 | 0.326 | - |
| Lead as Pb | ppm | 1.19 | 2.08 | 1.98 | 0.86 | 150 |
| Mercury as Hg | ppm | 0.23 | 0.25 | 0.26 | 0.21 | 15 |
| Cadmium as Cd | ppm | 0.90 | 0.82 | 0.64 | 0.88 | 45 |
| Arsenic as | ppm | 0.55 | 0.62 | 0.91 | 0.44 | 150 |
| Cyanide as Cn | ppm | ND | ND | ND | ND | 50 |
| Chromium as Cr+6 | ppm | ND | ND | ND | ND | 250 |
| **Item** | **Unit** | **Gandhi Maidan** | **Rajendra Nagar** | **Khemni Chak** | **New ISBT** | **Japan** |
| pH | - | 7.97 | 8.14 | 8.74 | 8.40 | - |
| Electrical Conductivity | mS/cm | 0.634 | 0.269 | 0.129 | 0.137 | - |
| Lead as Pb | ppm | 0.79 | 1.02 | 1.22 | 0.93 | 150 |
| Mercury as Hg | ppm | 0.22 | 0.27 | 0.31 | 0.42 | 15 |
| Cadmium as Cd | ppm | 0.68 | 0.72 | 0.79 | 0.95 | 45 |
| Arsenic as | ppm | 0.58 | 0.86 | 0.98 | 0.74 | 150 |
| Cyanide as Cn | ppm | ND | ND | ND | ND | 50 |
| Chromium as Cr+6 | ppm | ND | ND | ND | ND | 250 |

Source: JST, Notification of the National Environmental Board: Soil Quality Standard" in the Royal Gazette on 11 March 2021, Thailand, Environmental Quality Standards for Soil, Japan

### (2) Prediction

As mentioned in the sub-chapter of "Waste", it is expected that land modification will be expected, at a depot area, at the pier construction sites, TBM section, ramp section, and every underground station sites, with a total of 2,232,568 $m^3$ of excavated soil. There are plans to reuse the excavated soil generated from the sites for the embankment section of the expressway "Loknayak Ganga Path" under construction and the soil filling for a depot construction of Patna Metro. Therefore, since it can be said that there are some impacts on soil contamination, periodical soil monitoring analysis should be conducted to find early detection of soil contamination. During the construction phase, regular maintenance and inspection for heavy machinery should be carried out to prevent oil leaks. During the operation phase, oil traps, septic tanks, and drainage ditches should be installed at the proposed depot as mitigation measures to prevent the spread of soil contamination to the surrounding area.

## 14.6.5 Noise and Vibration

### (1) Survey

#### 1) Noise

A noise survey was conducted in February 2020 during dry season, and in July 2022 during the rainy season. Day and night time-averaged noise levels are shown below and compared with Indian standards for commercial areas, because all of the point is located at main road side whose category is designated as commercial area. The environmental noise quality was recorded for 24 hours by using Digital Sound

Level Meter. The values at all points, except PMCH, Khemni Chak, ISBT, and Patna Univ. during the day time in dry season, and Gandhi Maidan during the day time in rainy season, exceeded the environmental standard of India. Especially the values during rainy season were higher than the dry season due to the severe traffic congestion by raining. Standard values for noise in India are stipulated in EPA-1986, Noise pollution (Regulation Control), Rule-2000, PCLS / 02/1992, IV$^{th}$ Edition.

**Table 14-28: Standard of India**

| Category of Area/Zone | Day Time | Night Time | Regulation |
|---|---|---|---|
| I. Industrial Area | 75 dB | 70 dB | EPA-1986, Noise pollution (Regulation Control), Rule-2000, PCLS/02/1992, IV$^{th}$ Edition. |
| II. Commercial Area | 65 dB | 55 dB | |
| III. Residential Area | 55 dB | 45 dB | |
| IV. Silence Area | 50 dB | 40 dB | |
| Industrial Area/ Commercial Area | 70 dB | 70 dB | Environmental, Health, and Safety Guidelines, IFC |
| Residential Area | 55 dB | 45 dB | |

Source: EPA-1986, Noise pollution (Regulation Control), Rule-2000, PCLS/02/1992, IV$^{th}$ Edition./ Environmental, Health, and Safety Guidelines, IFC

**Table 14-29: Result of Noise level in dry season**

| Location name & Land mark | | Unit | Day time (AM 6:00 – PM 10:00) | | | | Night time (PM 10:00- AM 6:00) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lmax | Lmin | Leq | Standard | Lmax | Lmin | Leq | Standard |
| 1 | Danapur | dB(A) | 86.5 | 59.3 | **70.4** | 65 | 79.6 | 47.4 | **59.8** | 55 |
| 2 | Raja Bazar | | 78.2 | 58.7 | **68.7** | | 73.7 | 48.9 | **60.2** | |
| 3 | Patna Zoo | | 81.1 | 56.5 | **67.4** | | 76.2 | 45.3 | **57.7** | |
| 4 | Patna Junction | | 104.8 | 67.9 | **76.3** | | 80.8 | 46.3 | **67.5** | |
| 5 | Mithapur | | 86.7 | 61.5 | **73.2** | | 77.1 | 51.8 | **62.3** | |
| 6 | PMCH | | 79.4 | 51.0 | 60.8 | | 77.9 | 42.6 | 51.4 | |
| 7 | Patna University | | 83.1 | 56.5 | **66.2** | | 78.6 | 45.8 | 50.9 | |
| 8 | Khemni Chak | | 80.9 | 49.6 | 63.8 | | 76.2 | 46.1 | 54.1 | |
| 9 | New ISBT | | 76.2 | 51.1 | 58.2 | | 68.9 | 43.4 | 50.5 | |

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Table 14-30: Results of Noise Level in rainy season**

| Location name | | Unit | Day time (AM 6:00 – PM 10:00) | | | | Night time (PM 10:00- AM 6:00) | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | Lmax | Lmin | Leq | Standard | Lmax | Lmin | Leq | Standard |
| 1 | R.P.S. More | dB(A) | 104.5 | 55.2 | **74.3** | 65 | 85.1 | 50.3 | **60.1** | 55 |
| 2 | Raja Bazar | | 108.2 | 56.7 | **77.6** | | 93.1 | 72.6 | **74.3** | |
| 3 | Patna Zoo | | 104.1 | 56.6 | **73.1** | | 82.6 | 57.1 | **61.9** | |
| 4 | Patna Junction | | 91 | 43.4 | **68.1** | | 102.6 | 41.8 | **69.1** | |
| 5 | Gandhi Maidan | | 90 | 49.9 | 64.2 | | 78.3 | 47.8 | **56.8** | |
| 6 | Rajendra Nagar | | 98.7 | 57.8 | **75.2** | | 95.2 | 70.8 | **73.9** | |
| 7 | Khemni Chak | | 91.8 | 46 | **68.7** | | 90.7 | 57.3 | **71.5** | |
| 8 | New ISBT | | 107.2 | 42.5 | **73.0** | | 91.2 | 58.7 | **66.4** | |

Source: JST, Noise Regulation (Pollution & Control) Rules 2000

### 2) Vibration

A vibration survey was conducted in February 2020 during the dry season, and in July 2022 during the rainy season at the same time as the noise survey, and the results are as follows. Since the results are integrated day and night, it is unknown whether the results exceed the standard, but it is assumed that the impact of road traffic vibration along the Corridors will be large. Since there is no reference standard value for vibration in India, Vibration levels are compared with the vibration limits specified FTA-VA-90-1003-06 specifications for Reinforced-concrete, steel/timber (no plaster) Building because of the same calculation method. As a result of the survey, vibration levels at all sites are below FTA limits in both seasons. Overall, the values in the rainy season are higher than those in the dry season, but the survey locations and the distance from the point to the roadway are different in each season, so it is meaningless to compare the values of both seasons.

**Table 14-31: Results of Vibration Level in dry season**

| Location name | | Max Value | | FTA (dB) |
|---|---|---|---|---|
| | | V rms (mm/s) | V dB | |
| 1 | Raja Bazar | 0.11 | 72 | 102 |
| 2 | Patna Zoo | 0.19 | 77 | |
| 3 | Patna Station | 0.16 | 76 | |
| 4 | Gandhi Maidan | 0.05 | 66 | |
| 5 | Rajendra Nagar | 0.13 | 74 | |

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC, TRANSIT NOISE AND VIBRATION IMPACT ASSESSMENT: FTA-VA-90-1003-06 (USA)

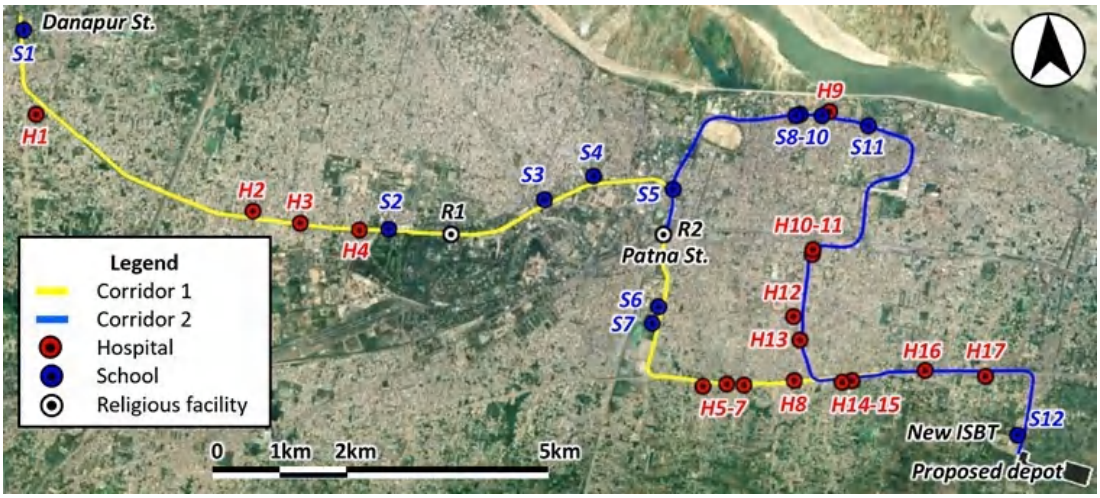
**Table 14-32: Results of Vibration Level in rainy season**

| Location name | | Max Value (dB) | | FTA (dB) |
|---|---|---|---|---|
| | | V rms (mm/s) | V dB | |
| 1 | Rukanpura | 0.38 | 83 | 102 |
| 2 | Raja Bazar | 0.64 | 88 | |
| 3 | Patna Zoo | 0.51 | 86 | |
| 4 | Patna Junction | 0.25 | 80 | |
| 5 | PMCH | 1.27 | 94 | |
| 6 | Ramakrishna Nagar | 0.64 | 88 | |
| 7 | Gandhi Maidan | 0.51 | 86 | |
| 8 | Khemni Chak | 0.64 | 88 | |

Source: JST, TRANSIT NOISE AND VIBRATION IMPACT ASSESSMENT: FTA-VA-90-1003-06 (USA)

### 3) Sensitive receptor

Regarding sensitive receptors there are some hospitals, schools and religious facilities which are located in the vicinity of the alignment. The details are given in the table and figure below.




Source: DPR

**Figure 14-23: Details of sensitive receptors along Patna metro**

**Table 14-33: List of sensitive receptors along Patna metro**

| HOSPITALS | | Distance from alignment (m) | SCHOOLS | | Distance from alignment (m) |
|---|---|---|---|---|---|
| **H1** | **Bimal Hospital** | 145 | **S1** | **Kendriya Vidyalaya Danapur** | 55 |
| H2 | Royal Hospital | 120 | S2 | JD Women's College | 46 |
| H3 | Paras HMRI Hospital | 24 | S3 | Dr. Zakir Hussain Institute | 50 |
| H4 | Shekhar Hospital | 22 | S4 | Patna Women's College | 135 |
| **H5** | **Patna Central Hospital** | 53 | S5 | National Institute of Fashion Technology | 19 |
| **H6** | **Vatsalya Advance Children Hospital** | 19 | S6 | Aryabhatta Knowledge University | 13 |
| **H7** | **Apex Hospital** | 16 | S7 | Amity Global Business School | 27 |
| **H8** | **Pulse Emergency Hospital** | 32 | S8 | Dental College | 16 |
| H9 | PMCH | 16 | S9 | Public Health Institute | 15 |
| H10 | Patna Boneand Spine Hospital | 21 | S10 | PMCH | 16 |
| H11 | Jeevak Heart Hospital | 21 | S11 | Patna University | 24 |
| **H12** | **Bihar Cancer Surgical** | 123 | **S12** | **RPS Public School** | 70 |
| **H13** | **Jaiguru Dev Hospital** | 13 | **RELIGIOUS** | | |
| **H14** | **Ford Hospital** | 36 | R1 | Panchmukhi Hanuman Mandir | 16 |
| **H15** | **Rachita Trauma Hospital** | 32 | R2 | Hanuman Mandir Patna Station | 23 |
| **H16** | **New Paramount Hospital** | 23 | | | |
| **H17** | **Earth Hospital** | 60 | | | |

Note: Receptors with bold letters are located at elevated section.

Source: DPR

## (2) Prediction

### 1) Construction phase

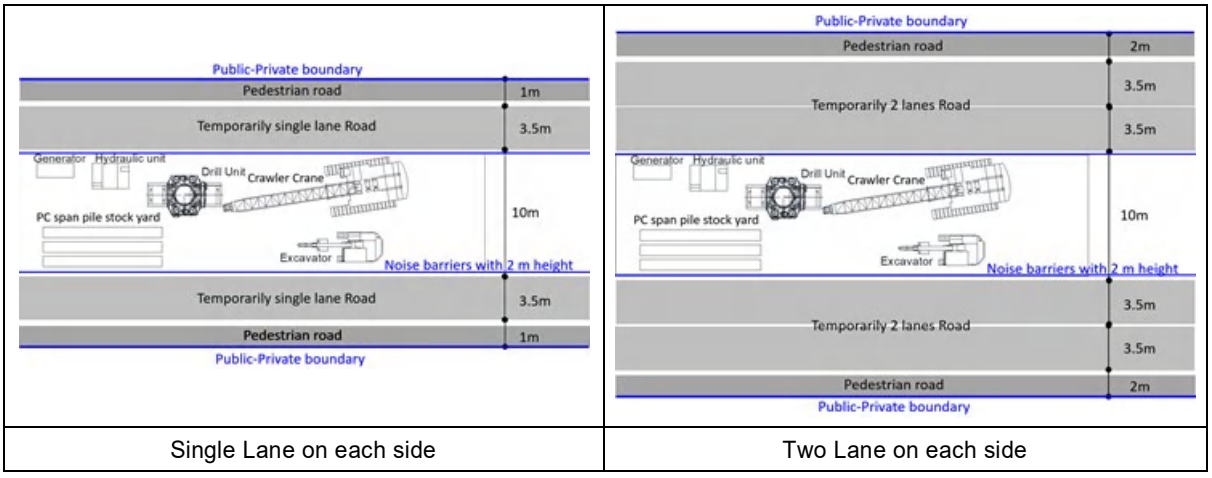
In the elevated and underground railway construction project, the work that generates the highest level of noise and vibration is pile driving activity for piers, so the noise and vibration level of the activity is the target of prediction. As one of the mitigation measures, the PC span pile with a hydraulic driver for

the pile driving method is proposed as a construction method. The general main construction machines are an excavator (0.7m$^3$), a crawler crane (70 ton), a hydraulic driver for pile driving, and a generator, which are shown in the table below with their output level of noise and vibration. It is assumed that these will be located at the central of the arterial road with 9 or10 m width in most of the elevated section, and the noise and vibration level at the road edge will be predicted. However, there is no standard for noise and vibration during construction in India. Therefore, the standard value regulated by the Tokyo Metropolitan Government should be referred to in this case.

**Table 14-34: Standards for regulation of noise generated by specific construction work**

| Construction activity | Tokyo, Japan |
|---|---|
| Pile driving work | 80 dB |

Source: Tokyo Metropolitan Environmental Security Ordinance, Tokyo Metropolitan Government




| Single Lane on each side | Two Lane on each side |
|---|---|

Source: JST

**Figure 14-24: Typical Construction Yard Arrangement of PC spun Pile**

**Table 14-35: Noise and vibration generated by construction machines for pile-driving works**

| | Construction machine | Noise power level (dB) (1m from machine side) | Vibration level (dB) (7m from machine side) |
|---|---|---|---|
| 1 | Excavator (0.7m$^3$) | 105 | 63 |
| 2 | Crawler crane (70 ton) | 101 | 40 |
| 3 | Hydraulic driver | 96 | 55 |
| 4 | Generator (200kVA) | 92 | 9 |

Source:

- Report on the Study and Testing of the Prevention and Elimination of Construction Noise and Vibration, 1979, Public Works Research Institute, Ministry of Construction, Japan
- Research on Methods of Prediction and Assessing Noise and Vibration Induced by Construction Works (Report No.1), 1981, Public Works Research Institute, Ministry of Construction, Japan
- ASJ Prediction Model 2007 for Construction Noise, 2007, Acoustical Society of Japan
- Noise and Vibration Countermeasure Handbook for Construction, 2009, Japan Construction Machinery and Construction Association

a) Noise

**i. Prediction procedure**

The noise level assessment during construction should be considered with the sound level generated by each construction machine located at a different position from the public-private boundary, and the Noise attenuation formula (1) should be used in this assessment. After the calculation, the attenuated noise level of each construction machine should be combined following the formula (2).

$$L_p = L_{p0} - 20log_{10}\left(\frac{r_0}{r}\right) \text{ -------- (1)}$$

Where

$L_{p0}$ : Noise power level at a distance $r_0$ from the origin

$L_p$ : Noise power level at a distance $r$ from the origin

$r_0$, $r$ : Distance from the origin at a sound level $L_{p0}$ and $L_p$ $(r_0 = 1m)$

$$L_{CN} = 10 \times \log_{10}\left(\sum_{i=1}^{n} 10^{\left(\frac{Lpi}{10}\right)}\right) \text{ -------- (2)}$$

Where

$L_{CN}$ : Combined Noise level

$L_{pi}$ : Noise power level at distance $r$ from the origin of each construction machine

$n$ : Number of Construction machine

**ii. Result of Noise prediction**

According to the result, the maximum noise power level from the construction activity is predicted as 77.5 dB for Single lane road and 73.3 dB for 2 lanes load respectively at 1.5m height on the Public-Private boundary. Then, the current noise level on the roadside at the same height obtained by the survey as a representative point is 74.3 dB and 77.6 dB each, which means that the predicted level is 79.2 dB and 79.0 dB for each. Therefore it can be said that these noise levels are below the standard value regulated by the Tokyo Metropolitan Government.

**Table 14-36: Result of Noise Prediction**

| Road type | Noise level of Survey | Prediction noise level | Combined noise level | Tokyo, Japan |
|---|---|---|---|---|
| Single lane on each side | 74.3 dB | 77.5 dB | 79.2 dB | 80 dB |
| 2 lanes on each side | 77.6 dB | 73.3 dB | 79.0 dB | |

Source: JST, Tokyo Metropolitan Environmental Security Ordinance, Tokyo Metropolitan Government

b) Vibration

**i. Prediction procedure**

The vibration level assessment during construction should be considered the same as the case of noise with the level generated by each construction machine located at a different position from the public-private boundary, and the vibration attenuation formula (1) should be used in this assessment. After the calculation, the attenuated vibration level of each construction machine should be combined following the formula (2).

$$VL = VL_0 + 15log_{10}\left(\frac{r_0}{r}\right)^n + 8.68(r_0 - r)\alpha \text{ -------- (1)}$$

Where

$VL$ : Vibration level at a distance $r$ from the origin

$VL_0$ : Vibration level at a distance $r_0$ from the origin

$r_0$, $r$ : Distance from the origin at a vibration level $VL_0$ and $VL$ $(r_0 = 7m)$

$n$ : Geometric attenuation Surface wave: $n$ = 0.5

$\alpha$ : Ground attenuation Clay layer: $\alpha$ = 0.02

$$L_{CV} = 10 \times \log_{10}\left(\sum_{i=1}^{n} 10^{(\frac{VLi}{10})}\right) \text{ -------- (2)}$$

Where

$L_{CV}$ : Combined Vibration level

$VLi$ : Vibration level at distance $r$ from the origin of each construction machine

$n$ : Number of Construction machine

**ii. Result of Vibration prediction**

According to the result, the maximum vibration level from the construction activity is predicted as 61.1 dB for Single lane road and 61.2 dB for 2 lanes load respectively at ground level on the Public-Private boundary. Then, the current maximum vibration level on the roadside at ground level obtained by the survey as a representative point is 92.4 dB and 100.4 dB for each, which means that the predicted level is 92.4 dB and 100.4 dB for each. Therefore it can be said that the predicted vibration level is extremely low not to affect the value of the maximum vibration level of the survey results, and combined vibration levels are still below FTA limits.

**Table 14-37: Result of Vibration Prediction**

| Road type | Max vibration level of Survey | Prediction vibration level | Combined vibration level | FTA limits |
|---|---|---|---|---|
| Single lane on each side | 92.4 dB | 61.1 dB | 92.4 dB | 102 dB |
| 2 lanes on each side | 100.4 dB | 61.2 dB | 100.4 dB | |

Source: JST, TRANSIT NOISE AND VIBRATION IMPACT ASSESSMENT: FTA-VA-90-1003-06 (USA)

2) Operation phase

Regarding the noise and vibration from Patna Metro operation, since noise problem hardly occurs in underground section in India due to the predominance of road traffic noise, and there is no authenticated noise prediction formula for underground sections internationally, noise and vibration prediction for elevated section, and vibration prediction for underground section shall be conducted.

a) Noise prediction for the elevated section

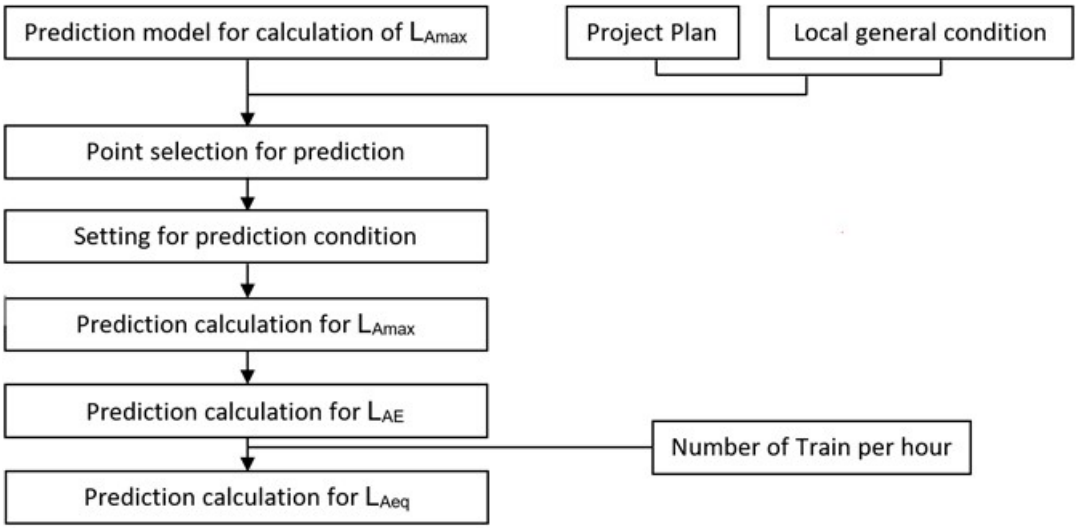
As mentioned in the subsection of air pollution, total traffic volume along Patna Metro will increase in the future, which means that the noise level in the vicinity of Patna Metro will be maintained or larger than the current condition. On the other hand, since the ratio of electric vehicles in the future will be grown by renewal from old types of gasoline automobiles, the future noise level may be reduced the

same as contemporary Japan[42]. Therefore, since it is difficult to predict future noise levels generated from road traffic, the numerical data from field surveys shall be utilized for the prediction accordingly.

### i. Prediction procedure

Noise level assessment on the operation stage will be following these steps;

1. To calculate the Maximum Noise level (LAmax) based on the cross-section structure and Train speed.
2. To calculate Single event noise exposure level (LAE) based on LAmax and train passage time.
3. To calculate the equivalent noise level (LAeq) based on the number of trains per hour




Source: Railway Technical Research Institute

**Figure 14-25: Prediction procedure for Railway Noise of elevated section**

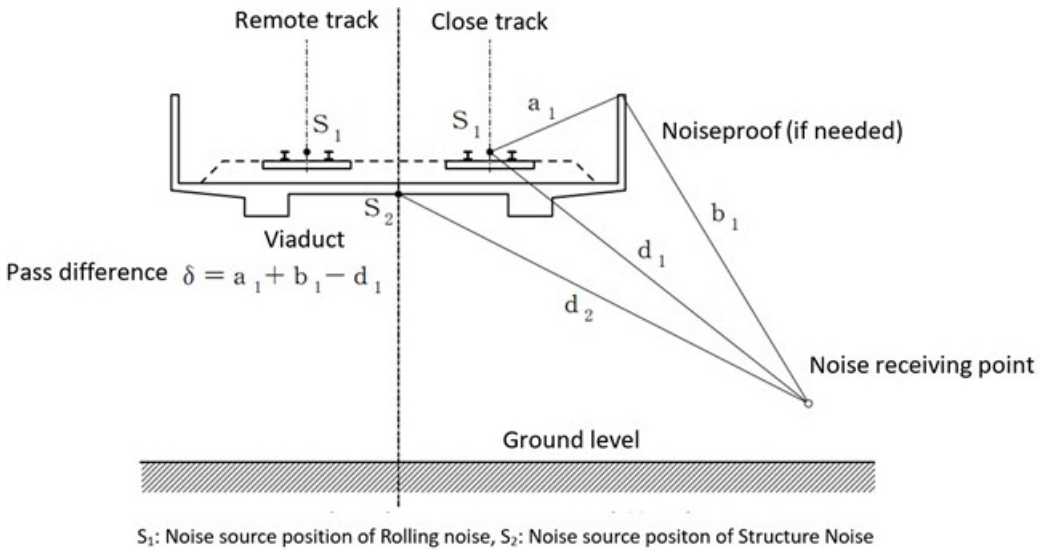
### ii. Prediction Model

An appropriate prediction model for Railway noise[43] suggested by Mr. Yoshio Moritoh (Railway Technical Research Institute, Japan) et al. can be utilized in the Patna Metro Rail Construction Project because of applying to several railway structural requirements such as Viaduct and Flat on the straight section. Since there are these requirements in the project, the model should be adopted. Since Metro running noise is compound of various noise types; Rolling noise, Structure noise, and Rolling stock device noise, these noises should be calculated and combined to the composite noise level.

### iii. Calculation of Maximum Noise level

The important information in the operation phase that will be utilized in this assessment is including; the number of train trips, length of the train, train speed, distance from the noise source, etc. The maximum Noise level (LAmax) is calculated by the three calculation formulas; (1), (2), and (3) as follows.

[42] https://www.jstage.jst.go.jp/article/jasj/75/4/75_188/_pdf, Acoustical Society of Japan, ASJ
[43] Proposal of a Prediction Model for Noise of Conventional Railway, the Institute of Noise Control Engineering of Japan, 1996.




Source: Railway Technical Research Institute

**Figure 14-26: Explanation of Noise source, Noise receiving point and Pass difference**

**iv. Rolling Noise**

$$L_{Amax}(\mathrm{R}) = PWL_R - 5 - 10log_{10}d_1 + 10log_{10}\left\{\frac{\left(\frac{l}{2d_1}\right)}{1+\left(\frac{l}{2d_1}\right)^2} + \tan^{-1}\left(\frac{l}{2d_1}\right)\right\} + \alpha_1 \quad \text{-------- (1)}$$

Where

$L_{Amax}(\mathrm{R})$ : Maximum Rolling Noise Level (dB)

$PWL_R$ : Power Level of Rolling Noise (dB)

$PWL_R = PWL_R\ (100) + 30log_{10}\ (\mathrm{V}/100)$

Slab track : $PWL_R\ (100)$ = between 100 and 105 dB

$d_1$ : Distance from track central point to Noise receiving point (m)

$l$ : Length of a train (m)

V : Train speed (km/h)

$\alpha_1$ : Shield attenuation by noise-proof (if needed) (dB)

**v. Structure Noise**

$$L_{Amax}(\mathrm{C}) = PWL_c - 5 - 10log_{10}d_2 + 10log_{10}\left\{\frac{\left(\frac{l}{2d_2}\right)}{1+\left(\frac{l}{2d_2}\right)^2} + \tan^{-1}\left(\frac{l}{2d_2}\right)\right\} + \Delta L_c \quad \text{-------- (2)}$$

Where

$L_{Amax}(\mathrm{C})$ : Maximum Structure Noise Level (dB)

$PWL_c$ : Power Level of Structure Noise (dB)$PWL_c = PWL_c\ (100) + 20log_{10}\ (\mathrm{V}/100)$

Concrete Viaduct

: $PWL_c\ (100)$ = between 83 and 87 dB

$d_2$ : Distance from a central point of Viaduct's undersurface to Noise receiving point (m)

$\Delta L_c$ : Correction value (dB)

If : r < 4h, $\Delta L_c = 0$, r > 4h, $\Delta L_c = -10log_{10}\left(\frac{r}{4h}\right)$

R : Horizontal distance between Viaduct's central point and Noise receiving point (m)

$h$ : Height of Viaduct's undersurface (m)

**vi. Rolling stock device noise**

$$L_{Amax}(\mathrm{M}) = PWL_M - 5 - 10log_{10}d_1 + 10log_{10}\left\{\frac{\left(\frac{l}{2d_1}\right)}{1+\left(\frac{l}{2d_1}\right)^2} + \tan^{-1}\left(\frac{l}{2d_1}\right)\right\} + \alpha_1 \quad \text{-------- (3)}$$

Where

$L_{Amax}(\mathrm{M})$ : Maximum Rolling stock device Noise Level (dB)

$PWL_M$ : Power Level of Rolling stock device Noise (dB)

$PWL_M = 60log_{10}(6.53\mathrm{V}/100) + \beta$

β : Slab track = 57 dB

$\alpha_1$ : Shield attenuation by noise-proof (if needed) (dB)

**vii. Maximum Noise level**

The maximum Noise level under train passage is calculated by synthesizing Rolling Noise, Structure Noise, and Rolling stock device noise (Calculation formula (1), (2), and (3)).

$$L_{Amax} = 10log_{10}\left(10^{\frac{L_{Amax(R)}}{10}} + 10^{\frac{L_{Amax(C)}}{10}} + 10^{\frac{L_{Amax(M)}}{10}}\right) \quad \text{-------- (4)}$$

Correlation between LAmax and LAE

Correlation between LAmax and LAE is calculated by a formula as follows.

$$L_{AE} = L_{Amax} + 10log_{10}(l/(1000V/3600))$$

**viii. Calculation of Equivalent Noise level**

Equivalent Noise level is calculated based on the LAE of each train passing direction and its number.

$$L_{Aeq} = 10log_{10}\left[\left(\sum_{i=1}^{n} 10^{L_{AEi}/10}\right)/3600\right] \quad \text{-------- (5)}$$

Where

$L_{AEi}$ : Single event noise exposure level of each train passing direction and its number

$n$ : Number of the train

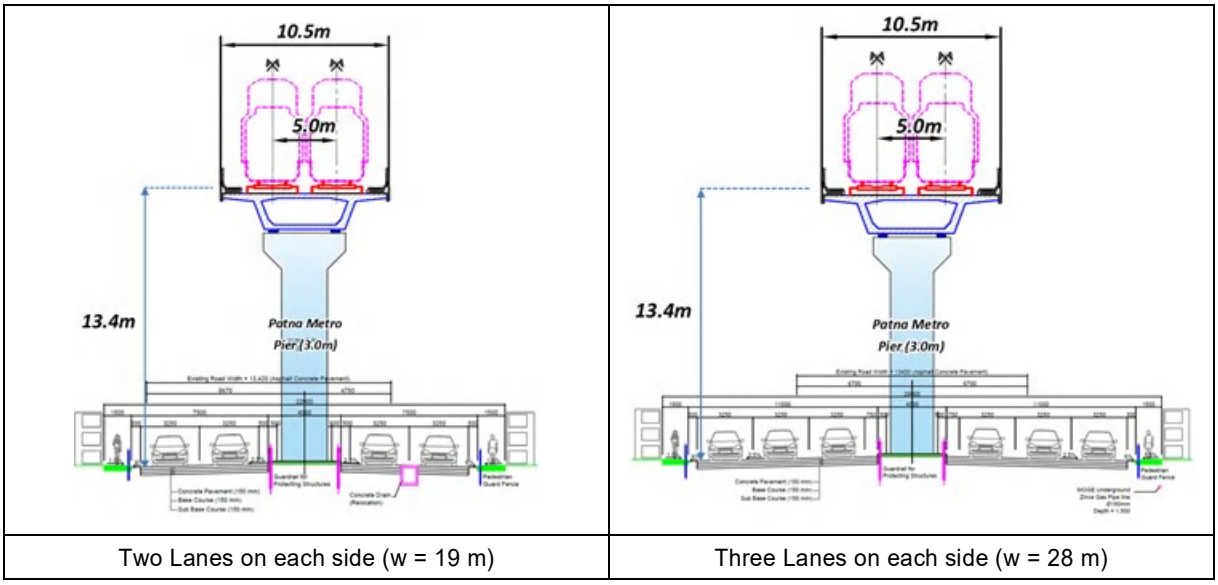
**ix. Prediction Condition**

Noise prediction for Patna Metro is implemented following the below condition.

**Table 14-38: Prediction Condition for Patna Metro**

| Item | | Condition |
|---|---|---|
| Prediction Point | Representative elevated straight points along Patna Metro | |
| Train Service | Number per hour | 12 trains/line |
| | Speed | 85 km/h (Maximum) |
| | Length | 65m or 129m (Corridor-1), 65m (Corridor-2) |
| Rolling Noise | $PWL_R$ | 100.38 dB |
| Structure Noise | PWLc | 83.59 dB |
| Rolling stock device Noise | $PWL_M$ | 101.66 dB |

Source: JST



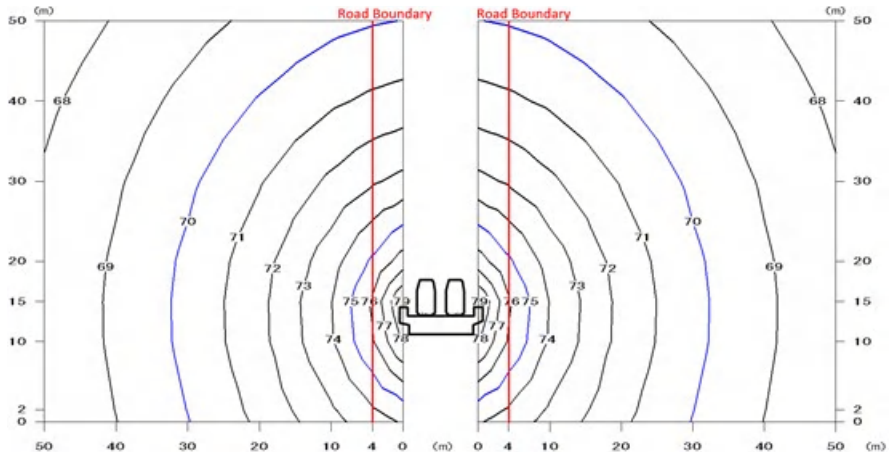

| Two Lanes on each side (w = 19 m) | Three Lanes on each side (w = 28 m) |
|---|---|

Source: JST

**Figure 14-27: Typical elevated cross section**

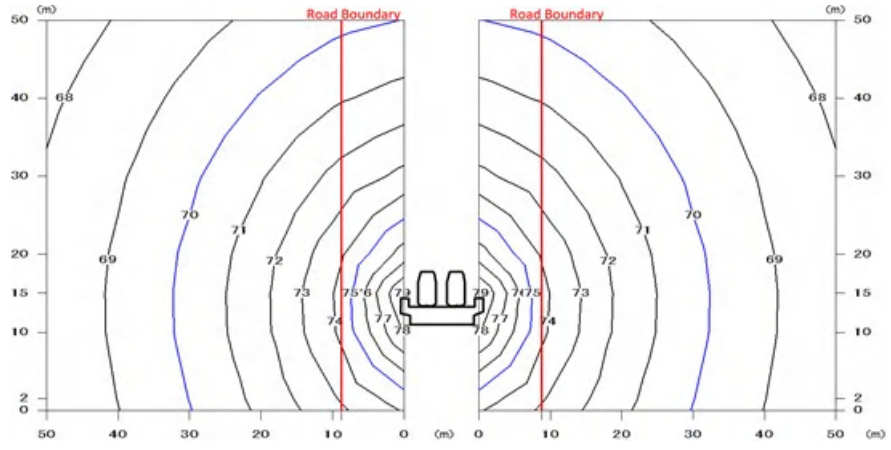
### x. Result of Noise prediction

From Table and Figures shown above and Calculation Formula (1), (2), (3), (4) and (5), the assessment shows the equivalent noise level, which is the national standard unit, from train passage without any noise-proof such as noise barrier, street trees, and any buildings, etc. Noise prediction results at the representative point along two lanes and three lanes show as below Figures with sectional noise contour.




Source: JST

**Figure 14-28: LAeq from Metro passage at the viaduct section with 2 lanes on each side**




Source: JST

**Figure 14-29: LAeq from Metro passage at the viaduct section with 3 lanes on each side**

**Table 14-39: Result of Noise Prediction**

| Road type | Noise level of Survey | Prediction Noise level | Combined Noise level | Standard |
|---|---|---|---|---|
| 2 lanes on each side | 74.3 dB | 73.9 dB (without NB)<br>57.1 dB (with 2m height NB) | 77.1 dB<br>74.4 dB | 65 dB |
| 3 lanes on each side | 77.6 dB | 73.1 dB (without NB)<br>56.6 dB (with 2m height NB) | 78.9 dB<br>77.6 dB | |

Note: NB: Noise Barrier

Source: JST

The prediction result shows that the Noise source level from Patna Metro passage is 73.9 dB for 2 lanes road on each side and 73.1 for 3 lanes road on each side at 1.5m on the boundary. Then, the current noise level on the boundary at 1.5m height obtained by the survey as a representative point is 74.3 dB and 77.6 dB respectively, which means that the noise level from Patna Metro contributes to the current noise level. Therefore, installing of noise barrier with 2m height on both sides of the elevated section shall be proposed as a mitigation measure. In this case, it is predicted that the noise level will be attenuated by approx. 15 dB, and it can be said that it hardly contributes to the current noise level.

Regarding sensitive facilities such as hospitals, schools and kindergartens, noise barriers should be installed not only for noise reduction but also for privacy protection. Additionally, since multi-storied buildings are standing on both roadsides, installing of the barrier also should be considered to secure the privacy and living environment of the residents.

### b) Vibration prediction for elevated section

Since a railway vibration has complicated generation and propagation paths and is affected by Rolling stock, tracks, and their structures, etc., no official prediction method has been established so far. Therefore, the prediction of railway vibration was carried out by a model formula, for slab track on the elevated section, created by analyzing the correlation between the train speed and the distance from the vibration source for the existing railway in Japan (1999, West Japan Railway Co., Ltd.). The prediction conditions are the same as noise prediction ones.

The model formula for Railway vibration[44]: $VL = 12.9 \times \log_{10} V - 13.2\log_{10} R + 39.3$

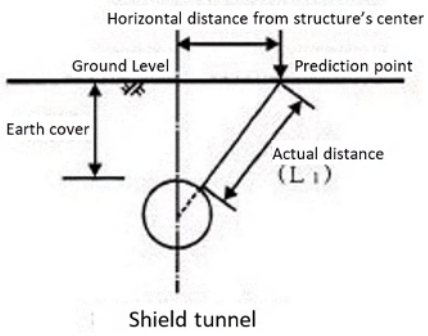
Where $V$ : Train speed (km/h)
$R$ : Distance from track central point to vibration receiving point (m)

The prediction result shows that the vibration level from Patna Metro passage is 51.3 dB for 2 lanes road on each side and 49.1 for 3 lanes road on each side at ground on the boundary. Then, the current vibration level on the boundary at ground obtained by the survey as a representative point is 86 dB respectively, which means that the vibration level from Patna Metro doesn't contributes to the current vibration level at all.

### c) Vibration prediction for underground section

As a method of vibration prediction for underground section of single shield tunnel, a prediction formula shown below which was suggested by Tokyo Metro Co., Ltd. (former Teito Rapid Transit Authority) is adopted in general.

$$VL = K - A \times \log L + 25 \times \log(V/50) - 24 \times \log(W/20) + X$$




Where
VL : Vertical vibration predicted level at a surface point of the earth (dB)
L : Actual distance from outside of the tunnel to a prediction point (m)

[44] "Environmental Impact Assessment for the Osaka outside loop-line Railway Construction Project" (1999, Osaka Soto-Kanjo Railway Co.,Ltd)

V : Velocity (V=85km/h)
W : Tunnel weight (16 tf/m)
K : Constant value for classified structure (K = 68dB)
A : Weighting factor of distance (Diluvium = 14)
X : Other weighting factor X = X1 + X2
X1 : Linear Correction (Straight section = 0)
X2 : Correction for reduction weight of rolling stock (All section = -5)

The prediction result shows that the vibration level from Patna Metro passage is approx. 54 dB at the section where the passage train has the maximum speed. Then, the current vibration level on the boundary at ground obtained by the survey as a representative point is 86 dB respectively, which means that the vibration level from Patna Metro doesn't contributes to the current vibration level at all.

#### 3) Sensitive receptor

According to the result of filed survey and prediction, impact of noise during the construction phase and operation phase at elevated section is expected. Therefore, some necessary mitigation measures should be taken in the both phases as below.

#### a) Construction phase

- Noise suppressors such as mufflers will be installed whenever deemed necessary to maintain the noise generated by various heavy equipment and other construction machinery within permissible limits.
- High noise-generating construction activities will be scheduled during daytime only (6:00 – 22:00) to avoid noise disturbance to adjacent residential and commercial areas and other noise-sensitive areas. In the case of educational facilities, the activities should be considered during the night time not to interfere with the class-works.
- Around the construction site is fenced as high as 2-2.5 m.
- Use low-noise and vibration machinery for construction such as piling

#### b) Operation phase

- Additional noise barriers shall be discussed, as needed
- At the station platform on elevated sections, paging and train melody volume shall be adjusted to the lowest level where it will not detract from their function.
- Slow speed in curve sections

### 14.6.6 Ground Subsidence

The results of the standard penetration test (SPT) of the existing geological investigation are not in the range of soft ground. Moreover, there is no possibility of any subsidence due to dewatering in the area along the proposed tunnels according to DPR.

When there is tunneling or huge underground excavation making a substantial gap in strata, there are chances of subsidence of upper strata. The construction of underground section involves the construction of

twin tunnels of 6 m in diameter each which will be done by using TBM. Considering the local geology, groundwater abundance and working technology, the probability of subsidence is very low. However, monitoring and countermeasure shall be done for the impact because there is still the possibility of ground subsidence in the construction areas and the damage will be serious if once occur.

### 14.6.7 Offensive odor

Possible points of offensive odor are related to waste / garbage generation, therefore, construction areas including camping yards during the construction phase and station including depot facilities during the operational phase might be the major locations. This impact depends on not only the collection system but also how to keep waste / garbage until collection at each location generally.

### 14.6.8 Protected Area

#### (1) Information collection

15 protected areas such as wildlife and bird sanctuaries, national parks and botanical parks have been designated in Bihar state. Among them, Sanjay Gandhi Botanical Park (hereinafter referred to as "SGB Park") is designated as a protected area along the Corridors. SGB Park was opened as a botanical garden in 1970 by the Forest Department of Bihar State for the purpose of forest conservation, and then the department changed the name to Biological Park in 1972. In the same year, the land of the adjacent Revenue Office and Public Works Bureau was transferred to the Forest Department, and the Government of Bihar declared that all forests within 61.6 ha in total would be designated as protected ones. In 1973, the Government opened the all area as a park-cum-zoo, and declared “Park-cum-Zoo services” as an essential administrative services under the Bihar Essential Services Maintenance Act (1948). Then the Park-cum-Zoo was renamed to the current name, SGB Park in 1980. Although SGB Park is designated as a protected area, it is managed by the Government of Bihar as Park-cum-Zoo because it is a valuable place for local people to be relaxed and recreate. Therefore, the management type is different from that of other natural protected areas which has risks disorderly destruction. In other words, in ordinary protected areas such as national parks and bird sanctuaries, managers are often absent, and the vast area makes it relatively easy for outsiders to enter. As a result, there is a high possibility of prohibited development activities, poaching, and theft.

**Table 14-40: Protected Area in Bihar**

| Name | Place /District | National Park / Sanctuary |
|---|---|---|
| Valmiki | West Champaran | National Park |
| Sanjay Gandhi | Patna | Botanical Park |
| Valmiki | West Champaran | Sanctuary |
| Bhimbandh | Monghyr | Sanctuary |
| Rajgir | Nalanda | Sanctuary |
| Kaimur | Rohtas | Sanctuary |
| Gautambudha | Gaya | Sanctuary |
| Udaypur | West Champaran | Sanctuary |
| Nagi Dam | Jamui | Bird Sanctuary |
| Nakti Dam | Jamui | Bird Sanctuary |
| Vikramshila Gangetic Dolphin | Bhagalpur | Sanctuary |
| Kanwar Jheel | Begusarai | Sanctuary |
| Gogabil Pakshi Vihar | Kaithar | Closed Area |
| Kusheshwarsthan | Darbhanga | Closed Area |
| Barela S.A.Z.S | Vaishali | Sanctuary |

Source: http://scstsenvis.nic.in/index4.aspx?ssslid=76&subsubsublinkid=428&langid=1&mid=1 (Environmental Information System (ENVIS))




Source: JST based on Google Earth

**Figure 14-30: Positional Relation between Patna Metro and SGB Park (Patna Zoo)**

Patna Zoo provided the list of animals including birds which are kept in enclosures/cages shown below. Some endangered species reared in the zoo are identified, but most of them are living in their enclosed spaces surrounded by trees as shown in the photo below. Therefore, noise, vibration, dust, etc. caused by construction work are expected to be largely mitigated.

**Table 14-41: Entrance and Inside of SGB Park (Patna Zoo)**






Source: JST

**Table 14-42: List of birds and mammals in enclosures/cages in Patna Zoo**

| No. | Scientific Name | Common Name | IUCN Category |
|---|---|---|---|
| **Birds kept in enclosures/cages** | | | |
| 1 | *Agapornis* | Love Birds | - |
| 2 | *Anas platyrhynchos* | Duck Mallard | LC |
| 3 | *Anser indicus* | Goose-Bar Headed | LC |
| 4 | *Anthracoceros malabaricus* | Hornbill-Indian pied | - |
| 5 | *Aro macao* | Scarlet Macaw | LC |
| 6 | *Bubo* | Owl-Indian Great Horn | LC |
| 7 | *Bubo nipalensis* | Owl Eagle Forest | LC |
| 8 | *Butastur teesa* | Buzzard | LC |
| 9 | *Cacatua galerita elonora* | Medium suplpher crested Cockatoo | - |
| 10 | *Cacatua galerita* | Greater suplpher crested Cockatoo | - |
| 11 | *Casuarius* | Cassowary | LC |
| 12 | *Chakophaps indica* | Emerald Dove | LC |
| 13 | *Chrysolophus amherstiae* | Pheasant-Lady Amherst | LC |
| 14 | *Chrysolophus pictus* | Pheasant-Golden | LC |
| 15 | *Cygnus atratus* | Black Swan | LC |
| 16 | *Dendrocygna javanica* | Lesser Whistling Duck | LC |
| 17 | *Dromaius novaehollandiae* | Emu | LC |
| 18 | *Elanus caeruleus* | Kite-Black Winged | LC |
| 19 | *Gallinula chloropus* | Moorhen | LC |
| 20 | *Gallus* | Red Jungle fowl | LC |
| 21 | *Gracula religiosa* | Myna-Hill | LC |
| 22 | *Grus antigone* | Crane-Sarus | VU |
| 23 | *Grus* | Crane-Common | LC |
| 24 | *Gyps himalayensis* | Vulture Himalayan Grffon | NT |
| 25 | *Leptoptilos javanicus* | Stork Adjutant (lesser) | LC |
| 26 | *Lophura nycthemera* | Pheasant-Silver | LC |
| 27 | *Melopsittacus undulatus* | Budgerigar | LC |
| 28 | *Milvus migrans* | Kite-Pariah/Black Kite | LC |
| 29 | *Mycteria leucocephala* | Painted Stork | NT |
| 30 | *Nycticorax* | Heron-Night | LC |
| 31 | *Nymphicus hollandicus* | Cockatiel | LC |

| No. | Scientific Name | Common Name | IUCN Category |
|---|---|---|---|
| 32 | *Pavo cristatus* | Peafowl | LC |
| 33 | *Pavo cristatus* | Peafowl-white | LC |
| 34 | *Pelecanus onocrotalus* | Pelican-Rosy/white | LC |
| 35 | *Primolium maracana* | Illiger's Macaw | NT |
| 36 | *Pseudibis papillosa* | Ibis-black | LC |
| 37 | *Psittacula cyanocephala* | Parakeet-Blossom Headed | LC |
| 38 | *Struthio* | Ostrich | - |
| 39 | *Tadorna ferruginea* | Duck-Brahmini | LC |
| 40 | *Tockus birostis* | Hornbill- Common Grey | - |
| 41 | *Treron phoenicoptera* | Yellow-legged green Pigeon | LC |
| 42 | *Treron phoenicoptera* | Pigeon-Common Green | LC |
| 43 | *Tyto alba* | Owl Barn | LC |
| **Mammals in enclosures/cages** | | | |
| 1 | *Antilope cervicapra* | Black Buck | LC |
| 2 | *Axis* | Deer-Spotted | LC |
| 3 | *Axis porcinus* | Deer-Hog | EN |
| 4 | *Boselaphus tragocamelus* | Nilgai- Blue Bull | LC |
| 5 | *Canis aureus* | Jackal | LC |
| 6 | *Canis lupus* | Wolf Indian | LC |
| 7 | *Cervus eldi thamin* | Deer Brow-antlered (Sangai) | EN |
| 8 | *Cervus unicolor* | Deer-Sambar | VU |
| 9 | *Elephas maximus* | Elephant-Indian | EN |
| 10 | *Equus quagga boehmi* | Zebra Grant | - |
| 11 | *Felis chaus* | Cat Jungle | LC |
| 12 | *Giraffa camelopardalis* | Giraffe | VU |
| 13 | *Hippopotamus amphibius* | Hippopotamus | VU |
| 14 | *Hyaena* | Hyena-Stripped | NT |
| 15 | *Hystrix indica* | Porcupine-Indian | LC |
| 16 | *Macaca mulatta* | Macaque-Rhesus | EN |
| 17 | *Macaca silenus* | Macaque-Lion tailed | EN |
| 18 | *Melursus ursinus* | Bear- Sloth | VU |
| 19 | *Muntiacus muntjak* | Deer-Barking | LC |
| 20 | *Pan troglodytes* | Chimpanzee | EN |
| 21 | *Panthera leo persica* | Lion Indian | - |
| 22 | *Panthera pardus* | Leopard / Panther | VU |
| 23 | *Panthera tigris* | Tiger-Royal Bengal | - |
| 24 | *Panthera tigris* | Tiger-white | - |
| 25 | *Paradoxurus hermaphroditus* | Civet-Common Palm | LC |
| 26 | *Presbytis entellus* | Langur-Common | VU |
| 27 | *Prionailurus viverrinus* | Fishing Cat | VU |
| 28 | *Rhinoceros unicornis* | Rhinoceros-Indian one horned | VU |
| 29 | *Rucervus duvaucelii* | Deer Swamp (Barasingha) | VU |
| 30 | *Selenarctos thibetanus* | Bear-Himalayan Black | VU |
| 31 | *Vulpes bengalensis* | Indian Fox | LC |

* Near Endangered (EN), Vulnerable (VU), Threatened (NT), Least Concerned (LC)

Source: Patna Zoo

### (2) Discussion with Patna Zoo

JST set a discussion opportunity with Patna Zoo staff to collect their opinion on Patna Metro construction and the animal list fed in the zoo. According to the discussion with them in September 2022, since their concerns have been raised to PMRCL for noise and vibration before, they communicated to the Special Secretary of Urban Development & Housing Department (UDHD) of Bihar state in 2019 and requested as below.

- The construction work should not affect to the Zoo boundary during construction.
- To minimize the impact of noise and vibration by taking necessary engineering methods during construction.

During the discussion, they again requested PMRCL to take necessary measures during the construction phase to avoid any inconvenience to the animal and birds fed in the zoo. In consideration of their opinion, PMRCL promised to take care of all concerns of Patna Zoo, and to give necessary instructions to the construction contractor before construction as mentioned in the EMP.

## 14.6.9 Ecosystem

The target area for Corridor 1, 2 and Depot begins from the Danapur cantonment to the Depot area through some commercial areas, residential areas, special areas and public areas. No major natural habitats have been confirmed except for Danapur Cantonment and SGB Park (Patna Zoo). It is also found that there is a strong pressure on natural ecosystems because of the rapid urbanization from farmland to residential areas according to the Google Earth image from 2002 to 2022 shown in below.



Satellite image 2002



Satellite image 2022

Source: JST based on Google Earth

**Figure 14-31: Satellite image at Danapur Cantonment area from 2002 to 2022**

### (1) Methodology

1) Flora

The study on the floral assessment for the project activity was based on field survey of the area. Inventory Methodology was adapted to the baseline data of floral diversity within 1 km radius along the both corridors using the relevant topographic sheets of scale 1:50000. A forest inventory is “an attempt to

describe the tree species and many of the characteristics of the land area upon which the trees are grown." The objective for this floral inventory of the study area, is to provide complete checklist of floristic structure along the corridors for formulating effective management and conservation measures.

#### 2) Fauna

A linear transect of 1.0 km each was chosen for sampling at each site. Each transect was trekked for 1.5 hours for the sampling of faunal diversity through following methods for different categories. For the sampling of butterflies, the standard 'Pollard Walk' method was employed and all the species recorded. Voucher specimens of the species that could not be identified in the field were collected using a butterfly net besides photographing them. For bird's sampling, 'Point Sampling' along the fixed transect (Foot trails) was carried out. All the species of birds were observed through a binocular and identified with the help of field guide book and photographs. For the sampling of mammals, direct count on open width (20m) transect was used. In addition, information on recent sightings/records of mammals by the villagers/locals was also collected. For carnivores, indirect sampling was carried out and the mammals were identified by foot marks, feces and other marks/sign created by them. In case of reptiles mainly lizards were sampled by direct count on open width transects. The study of fauna takes substantial amount of time to understand the specific faunal characteristic of area. The assessment of fauna has been done by extensive field survey of the area. During survey, the presence of wildlife was also inhabitants depending on animal sightings and the frequency of their visits in the project area which was later confirmed from forest department, Wildlife Department etc.

### (2) Survey

#### 1) Flora

Ecosystem surveys including the inventory survey along the Corridors including a proposed depot area have been conducted in July 2020 and 2022. As results of the surveys, the alignment does not pass through any forest area and there is no tree in the depot area. Trees have been found of indigenous and common species like Euclyptus, Ficus, Jamun, Neem, Palm, Babool, Ber, Gulmohar and other trees. Among herbs species, weed are commonly reported along the alignment. Commonly reported weeds species are Congress grass (Parthenium hysterophorus), Lantana (Lantana Camara), Eipatorium trilpineve, Solanum xanthiocarpum and Datura (Dathura stromonium). The species of grasses reported along the banks are Cyanodon dactylon, Achyranthes aspera, Saccharum arundinaceum, Vetiveria zizanoides, Ludwigia parviflora, Rungia repens, etc. These are mainly reported along the road side area. A list of identified species is shown below. In total, 115 species were identified including Aegle marmelos and Pterocarpus marsupium which are classified as Near Threatened by the IUCN.

| | |
|---|---|
|  |  |
| Ficus bengalensis | Terminalia arjuna |
|  |  |
| Ziziphus mauritiana | Lagerstroemia speciosa |
|  |  |
| Croton bonplandianum | Delonix regia |
|  |  |
| Anthocephalus cadamba | Cassia siamea |

Source: JST

**Figure 14-32: Photograph of Floral Species**

**Table 14-43: Identified species along the alignments (Natural Vegetation)**

| No. | Family | Scientific Name | Local Name | IUCN Category |
|---|---|---|---|---|
| **Tree** | | | | |
| 1 | Rutaceae | *Aegle marmelos* | Bel | NT |
| 2 | Simaroubaceae | *Ailanthus excelsa* | Rukhdo | - |
| 3 | Apocynaceae | *Alstonia scholaris* | Saptparni | LC |
| 4 | Annonaceae | *Annona squamosa* | Sitafal | LC |
| 5 | Rubiaceae | *Anthocephalus cadamba* | Kadam | - |
| 6 | Mimosaceae | *Albizia lebbeck* | Kala Siris | LC |
| 7 | Moraceae | *Artocarpus heterophyllus* | Kathal | - |
| 8 | Meliaceae | *Azadirachta indica* | Neem | LC |
| 9 | Leguminosae | *Bauhinia variegata* | Kachnar, Papri | LC |
| 10 | Bombaceae | *Bombax ceiba* | Semal | LC |
| 11 | Arecaceae | *Borassus flabellifer* | Tad | - |
| 12 | Burseraceae | *Boswellia serrata* | Salai | - |
| 13 | Fabaceae | *Butea monosperma* | Palash | LC |
| 14 | Fabaceae | *Cassia fistula* | Amaltas | LC |
| 15 | Fabaceae | *Cassia javanica* | Cassia | LC |
| 16 | Caesalpineaceae | *Cassia siamea* | Kassod | LC |
| 17 | Fabaceae | *Dalbergia sissoo* | Shisham | LC |
| 18 | Fabaceae | *Delonix regia* | Gulmohar | LC |
| 19 | Ebenaceae | *Diospyros melanoxylon* | Kendu | - |
| 20 | Myrtaceae | *Eucalyptus globulus* | Eucalyptus | LC |
| 21 | Myrtaceae | *Eugenia jambolana* | Jambhul | LC |
| 22 | Moraceae | *Ficus benghalensis* | Bar, Bargad | - |
| 23 | Moraceae | *Ficus glomerata* | Gular | LC |
| 24 | Moraceae | *Ficus religiosa* | Peepal | LC |
| 25 | Bignoniaceae | *Jacaranda mimosifolia* | Neel Gulmohor | - |
| 26 | Lythraceae | *Lagerstroemia speciosa* | Jarul | - |
| 27 | Sapotaceae | *Madhuca indica* | Mahua | - |
| 28 | Anacardiaceae | *Mangifera indica* | Aam | DD |
| 29 | Meliaceae | *Melia azedarach* | Bakain | LC |
| 30 | Sapotaceae | *Mimusops elengi* | Bakul | LC |
| 31 | Moringaceae | *Moringa oleifera* | Sanjna | LC |
| 32 | Fabaceae | *Peltophorum ferrugineum* | Copper pod | - |
| 33 | Annonaceae | *Polyalthia longifolia* | Mast tree | - |
| 34 | Fabaceae | *Pongamia pinnata* | Karanj | LC |
| 35 | Fabaceae | *Pterocarpus marsupium* | Paisar | NT |
| 36 | Arecaceae | *Roystonea regia* | Royal Palm | LC |
| 37 | Dipterocarpaceae | *Shorea robusta* | Sal | LC |
| 38 | Myrtaceae | *Syzygium cumini* | Jamun | LC |
| 39 | Fabaceae | *Tamarindus indica* | Chinch | LC |
| 40 | Combretaceae | *Terminalia arjuna* | Arjun | - |
| 41 | Combretaceae | *Terminalia bellirica* | Bahera | LC |

| No. | Family | Scientific Name | Local Name | IUCN Category |
|---|---|---|---|---|
| 42 | Combretaceae | *Terminalia tomentosa* | Asan | - |
| 43 | Fabaceae | *Vachellia nilotica* | Acacia nilotica | LC |
| 44 | Rhamnaceae | *Ziziphus jujuba* | Bordi | LC |
| 45 | Rhamnaceae | *Ziziphus mauritiana* | Ber | LC |
| **Bamboo** | | | | |
| 46 | Poaceae | *Bambusa arundinacea* | Kanta bans | - |
| 47 | Poaceae | *Dendrocalamus strictus* | Bamboo | - |
| **Shrubs** | | | | |
| 48 | Alangiaceae | *Alangium salviifolium* | Ankula | LC |
| 49 | Malvaceae | *Abutilon indicum* | Kanghi | - |
| 50 | Acanthaceae | *Adhatoda vasica* | Vasaka | LC |
| 51 | Nyctaginaceae | *Bougainvillea spectabilis* | Boganvel | - |
| 52 | Apocynaceae | *Calotropis gigantea* | Rui | - |
| 53 | Asclepiadaceae | *Calotropis procera* | Shet-akanda | - |
| 54 | Fabaceae | *Cassia sophera* | Kolokasunda | - |
| 55 | Fabaceae | *Cassia tora* | Panwar | - |
| 56 | Solanaceae | *Datura metel* | Datura | - |
| 57 | Malvaceae | *Hibiscus rosa-sinensis* | Jaba | - |
| 58 | Convolvulaceae | *Ipomoea carnea* | Bara Kalmi | - |
| 59 | Verbenaceae | *Lantana camara* | Chotra | - |
| 60 | Lythraceae | *Lawsonia inermis* | Mehndi | LC |
| 61 | Apocynaceae | *Nerium indicum* | Kaner | - |
| 62 | Euphorbiaceae | *Ricinus communis* | Rehri | - |
| 63 | Apocynaceae | *Vinca rosea* | Sadaphuli | - |
| 64 | Rhamnaceae | *Ziziphus mauritiana* | Beri | LC |
| **Herbs** | | | | |
| 65 | Amaranthaceae | *Achyranthes aspera* | Apang | - |
| 66 | Asteraceae | *Ageratum conyzoides* | Dochunty | - |
| 67 | Amaranthaceae | *Amaranthus spinosus* | Katanotey | - |
| 68 | Amaranthaceae | *Alternanthera sessilis* | Garundi | LC |
| 69 | Papaveraceae | *Argemone mexicana* | Seyalkanta | - |
| 70 | Nyctaginaceae | *Boerhavia diffusa* | Punarnaba | - |
| 71 | Nyctaginaceae | *Boerhavia repens* | Ghodapuruni | - |
| 72 | Umbelliferae | *Centella asiatica* | Thankuni | LC |
| 73 | Cleomaceae | *Cleome viscosa* | Hurhure | - |
| 74 | Fabaceae | *Clitoria ternatea* | Gokarna | - |
| 75 | Commelinaceae | *Commelina benghalensis* | Kansiri | LC |
| 76 | Euphorbiaceae | *Croton bonplandianum* | Bon-tulsi | - |
| 77 | Caesalpiniaceae | *Cassia tora* | Chakundo | - |
| 78 | Cyperaceae | *Cyperus* spp. | Motha | - |
| 79 | Cyperaceae | *Cyperus rotundus* | Motha | LC |
| 80 | Papilionaceae | *Crotalaria retusa* | Atasi | - |
| 81 | Solanaceae | *Datura stramonium* | Dhatura | - |

| No. | Family | Scientific Name | Local Name | IUCN Category |
|---|---|---|---|---|
| 82 | Euphorbiaceae | *Euphorbia hirta* | Boro-karni | - |
| 83 | Rubiaceae | *Ixora coccinea* | Rangan | - |
| 84 | Mimosaceae | *Mimosa pudica* | Lajjabati | LC |
| 85 | Musaceae | *Musa x paradisiaca* | Kanch-kala | LC |
| 86 | Mosaceae | *Musa balbisiana* | Kodoli | LC |
| 87 | Lamiaceae | *Ocimum sanctum* | Tulasi | - |
| 88 | Asteraceae | *Parthenium hysterophorus* | Gajar Ghas | - |
| 89 | Solanaceae | *Physalis minima* | Bon-tepari | - |
| 90 | Phyllanthaceae | *Phyllanthus urinaria* | Hazarmani | - |
| 91 | Acanthaceae | *Ruellia tuberosa* | Popping pod | - |
| 92 | Solanaceae | *Solanum nigrum* | Kakmachi | - |
| 93 | Asteraceae | *Tridax procumbens* | Tridaksha | - |
| 94 | Typhaceae | *Typha angustifolia* | Patera | LC |
| 95 | Typhaceae | *Typha angustata* | Pankanis | LC |
| **Climbers** | | | | |
| 96 | Liliaceae | *Asparagus racemosus* | Satamuli | - |
| 97 | Caesalpiniaceae | *Bauhinia vahlii* | Gront | - |
| 98 | Combretaceae | *Combretum roxburghii* | Punk | - |
| 99 | Cucurbitaceae | *Coccinia grandis* | Telakucha | - |
| 100 | Dioscoriaceae | *Dioscorea bulbifera* | Gachalu | - |
| 101 | Dioscoriaceae | *Dioscorea oppositifolia* | Shora-alu | - |
| **Grasses** | | | | |
| 102 | Poaceae | *Apluda mutica* | Chunkarki | - |
| 103 | Poaceae | *Aristida depressa* | Lambi | - |
| 104 | Poaceae | *Chrysopogon fulvus* | Dholu | - |
| 105 | Poaceae | *Chrysopogon gryllus* | Dholu | - |
| 106 | Poaceae | *Chrysopogon montanus* | Dholu | - |
| 107 | Poaceae | *Cynodon dactylon* | Dhoob | - |
| 108 | Poaceae | *Eragrostis tenella* | Bharbusi | - |
| 109 | Poaceae | *Eragrostis unioloides* | Kush | LC |
| 110 | Poaceae | *Heteropogon contortus* | Lamb, Sariala | - |
| 111 | Poaceae | *Imperata cylindrica* | Oolu | - |
| 112 | Poaceae | *Pennisetum orientale* | Fountain Grass | LC |
| 113 | Poaceae | *Thysanolaena maxima* | Phulijharu ghas | - |
| **Others** | | | | |
| 114 | | *Andropogan contortus* | Surwal | - |
| 115 | | *Andropogon martinii* | Rohis | - |

* Near Threatened (NT), Least Concerned (LC), Data Deficient (DD), NE (Not Evaluated)

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC, JST, IUCN red list

### 2) Fauna

All sites of the project-affected area are completely covered with grasses & plantations along the road sides and have no major faunal diversity except Danapur Cantonment and SGB Park (Patna Zoo). A complete checklist of fauna from project affected area and the surrounding of project affected area has been prepared. Lists of identified species are below. No mammal species are classified as endangered species on the IUCN Red List. 41 bird species were identified including Anhinga melanogaster, Mycteria leucocephala, Ciconia episcopus which are classified as Near Threatened under by the IUCN. In addition, 8 species of butterflies and 5 species of reptiles that are very common in the region were identified.



No.1 Anastomus oscitans



No.2 Anhinga melanogaster



No.3 Halcyon myrnensis



No.4 Ciconia episcopus



No.5 Mycteria leucocephala



No.6 Vanellus indicus

Source: JST (No.1-3), Charles J. Sharp (No.5), eBird (No.4,6 (https://ebird.org/home))

**Figure 14-33: Photograph of avifaunal Species**

**Table 14-44: Identified species along the alignments (Mammals)**

| No. | Scientific Name | Common Name | IUCN Category |
|---|---|---|---|
| 1 | *Funambulus pennantii* | Palm Squirrel | LC |
| 2 | *Semnopithecus entellus* | Common Langur | LC |
| 3 | *Macaca mulatta* | Monkey Rhesus | LC |
| 4 | *Suncus murinus* | Chachundar | LC |

Source: JST, IUCN red list

**Table 14-45: Identified species along the alignments (Avifauna)**

| No. | Family | Scientific Name | Common Name | IUCN Category |
|---|---|---|---|---|
| 1 | Podicipitidae | *Tachybaptus ruficollis* | Little Grebe | LC |
| 2 | Pelecanidae | *Pelecanus onocrotalus* | Great White Pelican | LC |
| 3 | Phalacrocoracidae | *Phalacrocorax carbo* | Great Cormorant | LC |
| 4 | | *Anhinga melanogaster* | Oriental Darter | NT |
| 5 | Ardeidae | *Ardeola grayii* | Indian Pond-Heron | LC |
| 6 | | *Ardea cinerea* | Grey Heron | LC |
| 7 | | *Ardea purpurea* | Purple Heron | LC |
| 8 | | *Butorides striata* | Striated Heron | LC |
| 9 | | *Nycticorax* | Black-Crowned Night Heron | LC |
| 10 | | *Bubulcus ibis* | Cattle Egret | LC |
| 11 | | *Casmerodius albus* | Great White Egret | LC |
| 12 | | *Egretta garzetta* | Little Egret | LC |
| 13 | Ciconiidae | *Mycteria leucocephala* | Painted Stork | NT |
| 14 | | *Ciconia episcopus* | Asian Woollyneck | NT |
| 15 | | *Anastomus oscitans* | Asian Openbill | LC |
| 16 | Threskiornithidae | *Pseudibis papillosa* | Red-naped Ibis | LC |
| 17 | Anatidae | *Tadorna ferruginea* | Ruddy Shelduck | LC |
| 18 | | *Sarkidiornis melanotos* | African Comb Duck | LC |
| 19 | | *Dendrocygna bicolor* | Fulvous Whistling-duck | LC |
| 20 | Dicruridae | *Dicrurus macrocercus* | Black Drongo | LC |
| 21 | Rallidae | *Amaurornis phoenicurus* | White-breasted Waterhen | LC |
| 22 | | *Gallinula chloropus* | Common Moorhen | LC |
| 23 | Cuculidae | *Eudynamys scolopaceus* | Western Koel | LC |
| 24 | Charadriidae | *Vanellus indicus* | Red-wattled Lapwing | LC |
| 25 | | *Pluvialis fulva* | Pacific Golden Plover | LC |
| 26 | | *Charadrius dubius* | Little Ringed Plover | LC |
| 27 | | *Tringa totanus* | Common Redshank | LC |
| 28 | Pycnonotidae | *Pycnonotus cafer* | Red-vented Bulbul | LC |
| 29 | Alcedinidae | *Ceryle rudis* | Pied Kingfisher | LC |
| 30 | | *Alcedo atthis* | Common Kingfisher | LC |
| 31 | | *Halcyon smyrnensis* | White-breasted Kingfisher | LC |
| 32 | Passeridae | *Passer domesticus* | House Sparrow | LC |
| 33 | Corvidae | *Corvus splendens* | House Crow | LC |
| 34 | Phoenicopteridae | *Phoenicopterus roseus* | Greater Flamingo | LC |
| 35 | Apodidae | *Apus* | Common Swift | LC |
| 36 | | *Apus affinis* | Little Swift | LC |
| 37 | Psittaculidae | *Psittacula krameri* | Rose-ringed Parakeet | LC |
| 38 | Columbidae | *Columba livia* | Rock Dove | LC |
| 39 | | *Streptopelia decaocto* | Eurasian Collared-dove | LC |
| 40 | Leiothrichidae | *Turdoides striata* | Jungle Babbler | LC |
| 41 | Sturnidae | *Acridotheres tristis* | Common Myna | LC |

Source: JST, IUCN red list

**Table 14-46: Identified species along the alignments (Butterflies)**

| No. | Scientific Name | Common Name | IUCN Category |
|---|---|---|---|
| 1 | *Catopsilia crocale* | Common Emigrant | - |
| 2 | *Eurema hecabe* | Common Grass Yellow | - |
| 3 | *Phalantha* | Common Leopard | - |
| 4 | *Precis lemonias* | Lemon Pansy | - |
| 5 | *Hypolimnas bolina* | Great Eggfly | - |
| 6 | *Ariadne merione* | Common Castor | - |
| 7 | *Danaus chrysippus* | Plain tiger | LC |
| 8 | *Hypolimnas misippus* | Danaid Eggfly | LC |

Source: JST, IUCN red list

**Table 14-47: Identified species along the alignments (Reptilia)**

| No. | Scientific Name | Common Name | IUCN Category |
|---|---|---|---|
| 1 | *Bufo stomaticus* | Marble Toad | LC |
| 2 | *Calotes versicolor* | Common garden lizard | LC |
| 3 | *Duttaphrynus melanostictus* | Common Indian Toad | LC |
| 4 | *Hemidactylus flaviviridis* | Northern House gecko | LC |
| 5 | *Euphlyctis hexadactylus* | Indian pond frog | LC |

Source: JST, IUCN red list

### 3) Habitat Area

Danapur Cantonments is located along the Corridors as an Important Bird Area (IBA) as well as a Key Biodiversity Area (KBA) and is under the jurisdiction of the Indian Army so it is protected from general human disturbance. Since KBA is defined by expanding it to species other than birds using the IBA Criteria, IBA is included in definition of KBA. Therefore it will be referred to as Danapur Cantonment KBA from this chapter onwards. According to the Important Bird and Biodiversity Areas in India, Priority sites for conservation[45] published in 2016, the following table is the key species which were not identified as vulnerable species in the IUCN Red List. However, depending on the habitat conditions of the key species, it may fall under the category of "critical habitat" in the JICA guidelines. Therefore, the field survey and secondary survey was conducted to identify key species and collect the habitat status mainly along the KBA of the Corridors in order to determine whether it is a critical habitat or not. The Corridor will pass on the Bally Road, which is one of the main roads in Patna, located in Danapur Cantonment KBA shown below.

[45] Important Bird and Biodiversity Areas in India, Priority sites for conservation, 2016, Bombay Natural History Society

**Table 14-48: Key Species for KBA designation**

| General name | Scientific name | IUCN category | Identified in the survey |
|---|---|---|---|
| **Mammal** | | | |
| Nilgai | Boselaphus tragocamelus | LC | |
| Indian Grey Mongoose | Herpestes edwardsii | LC | |
| **Avifauna** | | | |
| Asian Openbill | Anastomus oscitans | LC | ✓ |
| Painted Stork | Mycteria leucocephala | NT | ✓ |
| **Flora** | | | |
| Common Indian Mango | Mangifera indica | DD | ✓ |
| Ashvattha tree | Ficus religiosa | LC | ✓ |
| Cluster fig | Ficus glomerata | LC | ✓ |
| Gum Arabic Tree | Acacia nilotica | LC | |
| Black Plum | Syzygium cumini | LC | ✓ |
| - | Tamarindus indica | LC | ✓ |
| - | Acanthocephalus indicus | NE | |
| - | Dalbergia sissoo | LC | ✓ |

* Near Threatened (NT), Least Concerned (LC), Data Deficient (DD), NE (Not Evaluated)

Source: Important Bird and Biodiversity Areas in India, Priority sites for conservation




Source: JST based on Important Bird and Biodiversity Areas in India, Priority sites for conservation

**Figure 14-34: Positional Relation between Patna Metro and KBA**



Source: JST

**Figure 14-35: Danapur Cantonment KBA on Bally Rd.**

#### 4) Tree counting

Tree counting survey was carried out in 2020 along the proposed alignment, and an additional survey was also implemented in 2022 for the station sites. Tree with Girth at Breast Height (GBH) 30 cm have been counted. The alignment does not pass through any forest area, and there is no tree in Depot area. The total number of trees found in the proposed metro corridor and the station sites are 864 trees on Corridor 1 and 506 trees on Corridor 2. Basically, PMRCL will transplant all of the trees from the original place to another one because no tree cutting is allowed in the Law of Bihar. If tree cutting is required, or if any trees died, PMRCL will plant four trees newly instead of one affected tree as a compensation planting. Some impacted trees have already been transplanted in the sections under construction, whose status is as follows as of December 2022. A total of 103 trees, whose girth are between 1 m to 4.9 m, have been identified for compensatory planting, and 412 trees, which is four times the number of trees. The planting cost is 1,152,000 INR and the cost of cutting and logging is 63,036 INR at PMRCL's expense. The logs will be handed over to the Forestry Department afterward. Regarding the species of counted trees, no endangered species of trees have been noticed during field survey. Trees have been found of indigenous origin and common species like Euclyptus, Pipal, Jamun, Neem, Palm, Babool, Ber, Gulmohar and other planted trees. These species are those that are suitable for the climatic conditions of this place[46].

### (3) Summary

Regarding Aegle marmelos and Pterocarpus marsupium which are classified as NT under the lower category of IUCN, their habitats have been identified through the tree counting survey. Therefore, mitigation measure of transplanting shall be taken or has already been taken in prior to the construction commencement. According to the fauna survey, some species, categorized as “Near Threatened”, are identified along the Corridor 1 and 2. Therefore, some mitigation measures should be taken to conserve the species as below.

- Site observation should be conducted before the construction commencement and during construction in order to confirmation of nesting and flying observed by the construction contractors.
- Countermeasures such as avoidance of construction during their breeding season should be considered if nesting or flying off the specified species is confirmed in the project area.

JST also asked experts’ opinion and advice to collect further mitigation measures, and Mr. Abhinav Sahay, Assistant Professor, Environmental Sciences, Amity University in Patna, responded to us and suggested some conservation measures to mitigate any adverse impacts due to the Patna Metro Rail Construction Project, which are as follows. Hence the proposed measures should be added in the EMP and EMoP.

- Compensatory afforestation with native trees.
- Reduction of noise pollution during night hours and within the environmental standards.
- Reduction of light pollution during night hours by keeping lights close to the ground, directed and shielded.

Regarding the issue of “Critical habitat”, Danapur Cantonment KBA shall be construed as a critical habitat. The reasons are as below.

[46] Updated Detailed Project Report for Metro Rail System in Patna, Jan 2021, PMRCL

- Painted Stork, categorized as "Near Threatened", is identified in the KBA area.
- Nearly 3% of the breeding population of the Asian Openbill in South Asia is found in the KBA area as of 2012[47].

On the other hand, this project does NOT lead to "significant conversion or significant degradation of critical natural habitats and critical forests" for the key species shown in the Table 14-43.

- Patna Metro construction in the KBA area shall be conducted within the boundary of Bally Rd., which is already developed. Additional development of the natural habitats area will be avoided.
- No significant conversion: the integrity of the critical natural habitat will NOT be significantly reduced due to the construction and operation.
- No significant degradation: the ecosystem function to conserve and maintain the native species in the KBA area will NOT decrease significantly due to the construction and operation.
- No species categorized as Critically Endangered (CR) and Endangered (EN), was identified in the survey
- Effective long-term mitigation measures and monitoring will be implemented.

From the above, it can be seen that the project complies with the JICA guidelines in this regard.

### 14.6.10 Hydrology

#### (1) Entire area of Patna Metro

According to the report on dynamic ground water resources of Patna district, 2020, the total annual ground water recharge of Patna district is 989,712,900 $m^3$, total annual ground water extraction from irrigation, industry and domestic sectors 553,295,900 $m^3$. Therefore, it can be said that the current stage of ground water development is 55.9%, which means that the stage of Patna district falls under "Safe category according to the index of Stage of Ground Water Extraction as shown in the table below. Also, the pre monsoonal and post monsoonal depth to water level varies from 4.8 - 13.82 Meters Below Ground Level (mbgl) to 3.85 - 13.27 mbgl in the study area.

**Table 14-49: Categorization of Assessment Unit Based on Quantity**

| Stage of Ground Water Extraction | Category |
|---|---|
| Less than 70% | Safe |
| From 70% to 90% | Semi-Critical |
| From 90% to 100% | Critical |
| Over 100% | Over Exploited |

Source: Dynamic Ground Water Resources of Bihar, 2020

#### (2) Underground section

Since some impact on hydrology around the project site including TBM sections will be estimated, some mitigation measure as below should be taken.

- Sheet pile should be installed at the excavation work site in order to water sealing
- Closed mold type of TBM should be used in order to keep groundwater pressure

[47] Important Bird and Biodiversity Areas in India, Priority sites for conservation

- Groundwater monitoring using construction well

### (3) Depot area

Regarding the depot area, there is no change in the amount of rainwater treated by the river, which flows south of the depot, before and after the construction. However, since the area is currently surrounded by rice paddies, it can be assumed that the rainfall will take time to reach the river as subsoil water. On the other hand, when it is in the operation phase, the rainfall on the roof of the facilities and on the paved surface will be drained into the river through installed rainwater pipes, which means that it takes less time to reach the river. Mitigation measures shall be required to prevent the overflow of water. Additionally, since embankment is scheduled at the construction phase, perforated sheet piles shall be required to secure groundwater flow, as well as to prevent landslides into the river during construction. On the other hand, since oily water will be generated by washing coaches and using oil for maintenance, it should be filtered in oil pits or septic tanks before flowing into the river.

## 14.6.11 Geology and Topography

According to a literature survey, there is no specified and valuable geology and topography in the study area. The terrain of Patna city is mostly flat. The average elevation of the project site area is ranges range from 48-63m above the mean sea level (MSL). Geomorphologically the study area is covered with active flood plain and older flood plain. The project area is completely covered by the alluvium formation formed by Ganga River and basement of the alluvium is Vaishali formation and lithologically charactered with sand, silt and clay. The country has been classified into different zones indicating the intensity of damage or frequency of earthquake occurrences. According to the Bureau of Indian Standards, the city falls under seismic zone-IV, in a scale of II to V (in order of increasing proneness to earthquakes).

## 14.6.12 Land Acquisition/ Resettlement

Details of Land Acquisition and Resettlement are reported in the SIA chapter (Chapter 15).

## 14.6.13 Poverty

Details of Poverty are reported in the SIA chapter (Chapter 15).

## 14.6.14 Indigenous and ethnic people

Indigenous people will not be affected by the Project. Details are reported in the SIA chapter (Chapter 15).

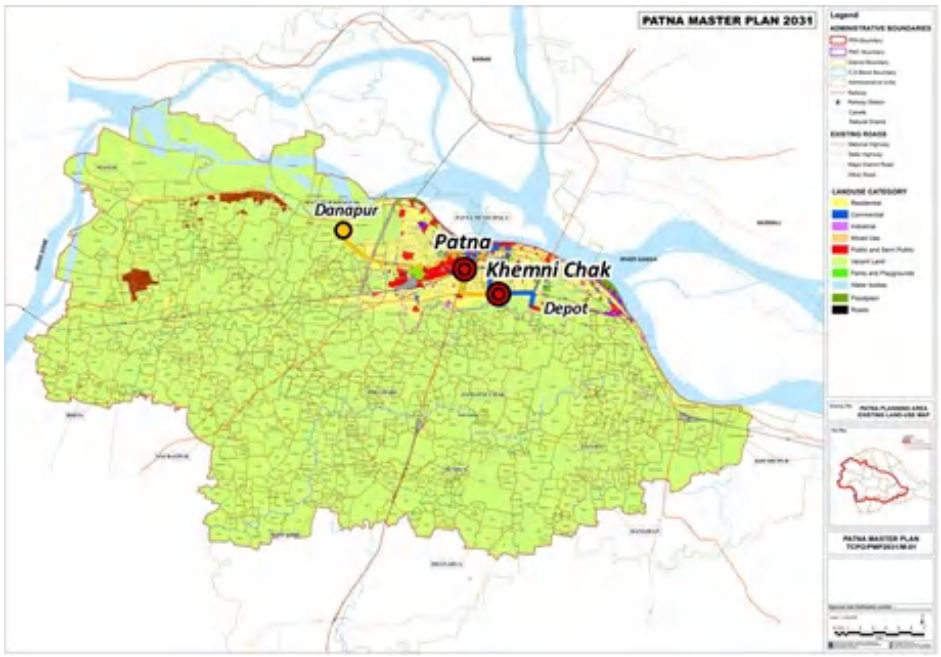
## 14.6.15 Local economy such as employment and livelihood, etc.

Details on the impacts on livelihoods and other modes of transportation are reported in the SIA chapter (Chapter 15).

## 14.6.16 Land use, utilization of local resources and ecosystem services

Patna city is undergoing very rapid changes in land cover and land use due to population growth, economic development, migration, and infrastructural innovations

Since this project will be implemented in an already urbanized area, it will not bring about major changes in land use. However, the proposed depot area currently contains agricultural land and is subject to land use change. According to the site inspection and the interview with local farmers in and around the proposed depot area, seasonal vegetables, paddy, wheat and millet are generally cultivated there, and the cultivation area (Light green colour zone in the below figure) spreads widely to the east and south from the depot area. Therefore, it can be said that a minor impact on land use and utilization of local resources expected. Additionally, JST conducted another interview survey for Land use and utilization of local resources including ecosystem services with 10 local people at each proposed station area in July 2022, which is 240 people in total. All of them opined that there would be no loss of land use or local resources by the project. On the other hand, regarding the question of ecosystem services, some of the respondents answered that they received ecosystem services by visiting Sanjay Gandhi Biological Park/ Patna Zoo as a relaxation and healing spot.




Source: Patna Master Plan 2031

**Figure 14-36: Existing land use map**

### 14.6.17 Water usage and its rights

According to the interview survey, water usage is mainly for daily use such as bathing, drinking, washing and other purpose. Water is not used for economic purpose such as fishing activity.

As for drinking water, 110 water supply centres and about 1500 km of water supply pipeline are operated by Patna Municipal Corporation (PMC). Therefore, all the respondents have told that they use water supplied through tap water provided by PMC for daily usage and there is no use of nearby river water or lake water for fishing, fishery, washing for laundries and dishes etc.in the daily life.

### 14.6.18 Existing social infrastructures and services

#### (1) Sensitive receptors

According to the results of the field survey, there are 17 hospitals, 12 educational facilities such as schools and universities, and 2 religious facilities. As mentioned in the Noise and vibration part, some noise impact will be generated at the construction phase and operation phase along the Corridors. Therefore, some necessary mitigation measures should be taken in the both phases.

#### (2) Transport services

1) Bus

At present, bus service provided by Bihar State Road Transport Corporation (BSRTC) and three-wheel Auto including rickshaws are used by the citizens in Patna.

According to the information collected from BSRTC office, the BSRTC buses have started to operate in the city since 2018. Total number of city buses are about 600; 350 private busses, 130 of PPP mode busses, 90 of Nigam Buses and 25 electric buses. Although these number of bus might be one factor of the traffic congestion in Patna city, total number of daily passengers are 38,000, which means that Bus transport services shall be essential for the citizens. However, even though it is a main means of transportation, bus passengers are very eager to welcome Patna Metro as they are facing the traffic accidents and very crowded in Buses according to the interview survey. So it can be said that they have no choice but to get on a bus. On the other hand, bus drivers are also willing to welcome Patna Metro as they expect to reduce of traffic volume on road, and to decrease accidents and honking which is the major problem in Patna city. The details are mentioned in the "Consideration on impacts on existing transportation industry" of SIA chapter.

2) Three wheel auto

JST also conducted another interview survey with 30 three-wheel auto drivers at Patna Junction, Gandhi Maidan, Saguna More and Mithapur. Most of them answered with satisfaction with Patna Metro Rail Construction Project and they added that they could have chances to drive short distance repeatedly by picking up passengers at the operation phase more often than now with the same as current cost. Because there are agents of three-wheel drivers who decide the rates and routes for drivers. The upcoming metro project will reduce the driving distance but will increase their number of trips per day. Overall, they are happy with the project. They also hope that the number of auto will be decentralized with each metro station, which may help them to get rid from the agents' harassment. The details are mentioned in the "Consideration on impacts on existing transportation industry" of SIA chapter.

### 14.6.19 Maldistribution of benefit and damage

The results of the interviews indicate that the most important requirement of the respondents is transportation, traffic management, noise pollution control, job opportunities, education and health facility. These conditions may be hindered during the construction period partially and temporally due to access

blocking by fencing and traffic control. As a result, some areas may receive negative impact on their livelihood and daily life temporally.

### 14.6.20 Local conflict of interest

As a result of the interview survey, respondents are expecting job opportunities in the Patna Metro Rail Construction Project during the construction and operational phase. Also, respondents are highly unsatisfied towards the current situation of Patna City regarding traffic safety, green environment, air pollution and noise pollution. Therefore, the Patna Metro Rail Construction Project will strongly contribute to improve not only the transportation conditions prominently securing the traffic conditions but also the atmospheric environment as the number of vehicles on the road will reduce. Local people will prefer to travel by Patna Metro, which will make the transport system for the people cheaper, safer and less time consuming.

### 14.6.21 Cultural Heritage

There is no cultural or historical heritage structure along the Corridors, but there are six heritage structures in Patna as shown in the table below. According to the Ancient Monuments and Archaeological Sites and Remains (Amendment and Validation) Act, 2010, all construction projects shall be regulated within 100 m from the boundary of the prohibited area and 200 m from the boundary of the regulated area, and the permission of Archaeological Survey of India (hereinafter referred to as "ASI".) shall be required. Although the closest heritage structure to the Corridors is Golghar, Patna, the separation of 290 m from the Corridor 2 is secured. Therefore, the permission of ASI for the project is not required. According to the vibration prediction using the formula mentioned in “Noise and vibration”, the result value at the closest point from Golghar, Patna is approx. 33 dB, which is negligible. Therefore it can be seen that no impact is occurred.

**Table 14-50: List of Heritage Structures in Patna**

| No. | Name of structure | Location | Closest St. | Distance from alignment |
|---|---|---|---|---|
| 1 | Palace of Ashoka | Kumrahar, Patna | Zero Mile | Approx. 1.55km |
| 2 | Bulandibagh | Bulandipur, Patna | Moin Ul Haq Stadium | Approx. 1.94km |
| 3 | Choti Pahari | Chhotipahari | Zero Mile | Approx. 0.70 km |
| 4 | Wooden foundations and ancient mauryan walls | Sandalpur | Moin Ul Haq Stadium | Approx. 1.25 km |
| 5 | Mir Ashraf’s Jama Mosque | Ashraf Masjid, Patna | Zero Mile | Approx. 3.78 km |
| 6 | Golghar, Patna | Ashok Rajpath, Patna | Gandhi Maidan | Approx. 0.29 km |

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC




*No.5 was omitted due to out of range on the Map

Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Figure 14-37: Location Map of Heritage Structure in Patna**

### 14.6.22 Landscape

The photos, taken in May 2022, at the representative point on Corridor 1 and 2 are shown as follows. As mentioned previously, the height of the Patna Metro viaduct is approx. 13.4 m. As of September 2022, there is some multiple storied building, along with the elevated section of Corridor 1 in which has 6 traffic lanes, and Corridor 2 in which has 4 traffic lanes.



Elevated section of Corridor-1 (R.P.S More)



Elevated section of Corridor-2 (Khemni Chak)

Source: JST

**Figure 14-38: Proposed sectional view and current situation**

It is considered that enough road width will be secured on Corridor 1 during the operation phase, and there will be less oppressive feeling from the Patna Metro viaduct. On the other hand, the parallel section with Corridor 1 and 2 will not have enough open space due to the 2 alignment on the 4 traffic lanes and a side road, so it would be better to install a wall greening panel as a mitigation measure to relieve the oppressive feeling. The colour of the panel should avoid eccentric vivid colours which are different from the surrounding landscape.

### 14.6.23 Gender

Details are mentioned in the "Consideration on Gender" of SIA chapter (Chapter 15).

### 14.6.24 Children's right

According to the past media releases[48], child labor cases are reported and the state government has been challenging to solve the issues through a number of schemes in collaboration with different agencies, including UNICEF, and other volunteers. According to the interview survey conducted in July 2022, all of the respondents opined that no child labour has been experienced in their community.

### 14.6.25 Health (Infectious diseases such as HIV/AIDS, etc.)

During the study, no cases of sanitation and infectious diseases were reported among the respondents in the study area. However, the most common diseases prevalent in the city are Cough, Cold, Diarrhea, Typhoid mainly higher during the rainy season and Diabetes. Besides that, risk of HIV/AIDS spread-out shall be considered among construction worker because that is a common social health risk. COVID-19 including the following variations are also the social health issue especially in crowded public space such as train coaches and stations.

### 14.6.26 Labor environment including labor safety

There are several laws and regulations on the labor environment in India, such as Industrial Relations Code (2020), Occupational Safety, Health and Working Conditions Code (2020), Code on Social Security (2020) and Code on Wages (2019). These principal laws shall be respected during the construction phase. The construction of the project includes variety of labor environment such as work at high places, work underground, work along with roads with traffic, and etc. Therefore, different types of risks to labor safety are expected during the construction stages.

### 14.6.27 Accidents

Annual traffic accident information for the city of Patna is shown in the table below. In 2019, the number of traffic accidents was high, with 460 accidents occurring. Despite the increase and decrease in the number of accidents, the number of fatal accidents is on the rise.

**Table 14-51: Traffic Accidents in Patna City**

| | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|
| Number of Traffic Accidents | 400 | 347 | 460 | 347 |
| Deaths recorded due to Traffic Accidents | 132 | 139 | 171 | 172 |
| Number of cases Injured due to Traffic Accidents | 213 | 198 | 286 | 223 |

Source: District transport office, Gandhi Maidan

### 14.6.28 Cross-border impact and Climate change

According to the DPR 2021, the annual vehicle km saved is shown below, and the Ministry of Housing and Urban Affairs (MoHUA) has issued the volume of pollutant (gram per km) including $CO_2$ for different

[48] https://timesofindia.indiatimes.com/city/patna/dy-cm-steps-taken-to-eradicate-child-labour/articleshow/92167716.cms

modes. Therefore, the $CO_2$ reduction effect due to the opening of the Patna Metro can be calculated as follows. $CO_2$ emission might be reduced by 58,111 (t-$CO_2$) in 2024, and by 128,631 (t-$CO_2$) in 2051, which can be said that Patna Metro will make a significant contribution to the reduction of greenhouse gases.

**Table 14-52: $CO_2$ reduction effect due to Patna Metro**

| Mode | Volume of $CO_2$ emitted (g/km-$CO_2$) | Annual Vehicle km saved (million km) | | | | Annual saved $CO_2$ emission (t-$CO_2$) | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 2024 | 2031 | 2041 | 2051 | 2024 | 2031 | 2041 | 2051 |
| Bus | 787.72 | 7.9 | 11.1 | 11.8 | 13.8 | 6,223 | 8,744 | 9,295 | 10,871 |
| Car | 139.52 | 95.8 | 168.8 | 175.9 | 207.3 | 13,366 | 23,551 | 24,542 | 28,922 |
| 2-Wheelers | 28.58 | 737.1 | 1146.8 | 1395.2 | 1735.3 | 21,066 | 32,776 | 39,875 | 49,595 |
| 3-Wheelers | 77.89 | 201 | 316.7 | 347.9 | 435.4 | 15,656 | 24,668 | 27,098 | 33,913 |
| Taxi | 139.52 | 12.9 | 23.5 | 32.6 | 38.2 | 1,800 | 3,279 | 4,548 | 5,330 |
| **Total** | | **1,055** | **1,667** | **1,963** | **2,430** | **58,111** | **93,017** | **105,358** | **128,631** |

Source: JST calculated through DPR

On the other hand, the Metro operation will produce some amount of greenhouse gases (GHG) by using electricity for its operation, the amount is not significant especially compared with the effect of reducing road traffic which produce much GHG. No other impact on cross-border and climate change was observed and expected.

## 14.7 Impact Assessment

This section describes the possible environmental and social impacts during the pre-construction, construction, and operation phase of the project. Predictions of the impacts were conducted based on the results of scoping, analysis of the project components, and the baseline data including field survey results.

Scoping for the project was discussed for both the main project and related facilities including quarry, borrow-pit, etc. However, the impact assessment for such related facilities shall be omitted because it has not been decided at the time of the feasibility study. Therefore, the prediction and evaluation of the environmental assessment for the items will be carried out in the following phases.

The result of the environmental and social impact assessment is shown in the table below along with the results of the assessment made earlier at the scoping stage to allow comparisons to be made

## Table 14-53: Results of Assessment for the Project

| Category | No. | Impact Item | Evaluation | | | | Reason for evaluation |
|---|---|---|---|---|---|---|---|
| | | | Scoping | | Based on Survey | | |
| | | | Pre-CS/CS | OS | Pre-CS/CS | OS | |
| Pollution | 1 | Air pollution | ✓ | ✓ | B- | B± | **CS:** Emission gas (NOx, SOx) and dust (PM) will have a temporary negative impact on the air quality by construction machineries and vehicles. (Baseline data showed PMS at each measuring point exceeded the standard) |
| | | | | | | | **OS:** - Positive impact will be offered by the decrease in traffic along the Patna metro lines.<br>- Pollutant concentration may be occurred around the ventilation facilities in the underground sections and substations. |
| | 2 | Water pollution | ✓ | ✓ | B- | B- | **CS:** - Turbid water will be generated in surface water and ground water along Patna metro due to civil works.<br>- Turbid water will be generated at a proposed site for depot due to soil filling works.<br>- There is a possibility of discharged organic wastewater from the base campsite. |
| | | | | | | | **OS:** There is a possibility of discharged organic wastewater from the toilet installed at every station and the depot. |
| | 3 | Waste | ✓ | ✓ | B- | B- | **CS:** - General waste and excreta will be generated from the base campsite.<br>- Construction waste such as soil and deforestation trees are generated.<br>- Muck due to tunnel excavation is generated and some of them may be not suitable for reuse. |
| | | | | | | | **OS:** General waste and excreta will be generated from every station and a depot. |
| | 4 | Soil contamination | ✓ | ✓ | B- | B- | **CS:** Oil leaks from construction equipment may cause soil contamination. |
| | | | | | | | **OS:** - Soil contamination may be generated at a depot due to oil leaks of heavy machine and rolling stock coating.<br>- Inappropriate management of transformer will cause oil leakage. Consequently, it will contaminate the soil. |
| | 5 | Noise and vibration | ✓ | ✓ | B- | B± | **CS:** Noise and vibration will be generated by construction machineries and vehicles. |
| | | | | | | | **OS:** Metro rail can reduce noise and vibration from road traffic by mode changes. Metro rail, however, may generate additional noise and vibration by itself at elevated sections. On the other hand, no impact on noise and vibration occurred at underground section according to the prediction result. |
| | 6 | Ground subsidence | ✓ | ✓ | B- | B- | **CS:** There is possibility of ground subsidence because of liquefaction under the elevated section, land filling at the deport area, and underground construction sections including stations. |
| | | | | | | | **OS:** There is no significant impact. However, monitoring in the operation phase should be necessary as a follow-up observation and maintenance. |
| | 7 | Offensive odor | ✓ | ✓ | B- | B- | **CS:** Offensive odor may occur depending on the volume of general waste etc. from construction sites and basecamp. |
| | | | | | | | **OS:** Offensive odor may occur depending on the volume of general waste etc. from every station and the depot. |

| Category | No. | Impact Item | Evaluation | | | | Reason for evaluation |
|---|---|---|---|---|---|---|---|
| | | | Scoping | | Based on Survey | | |
| | | | Pre-CS/CS | OS | Pre-CS/CS | OS | |
| Natural Environment | 8 | Protected area | ✓ | ✓ | B- | D | **CS:** Although Sanjay Gandhi Botanical Park (SGB Park or Patna Zoo) is designated as a protected area, it is managed by the Government of Bihar as Park-cum-Zoo, whose management type is different from that of other natural protected areas which risks disorderly destruction. However, the area may have ecological functions in urban environment of Patna. Therefore, general considerations to mitigate impacts from the project regarding pollution items shall be taken in both construction and operational phases. |
| | | | | | | | **OS:** No impact on noise and vibration occurred at underground section according to the prediction result. Because Sanjay Gandhi Botanical Park (SGB Park or Patna Zoo) is located near underground section of Patna Metro. |
| | 9 | Ecosystem | ✔ | ✔ | B- | B- | **CS:** - There is a negative impact on the ecosystem through deforestation of trees due to the construction of viaducts, underground stations and a depot.<br>- Since a partial section pass through Danapur Cantonment KBA, the impact on ecosystem, especially on avifaunal diversity, such as light pollution, noise and vibration are expected. |
| | | | | | | | **OS:** Since a partial section pass through Danapur Cantonment KBA, the impact on ecosystem, especially on avifaunal diversity, such as light pollution is expected. |
| | 10 | Hydrology | ✔ | | B- | D | **CS:** - Some impact on hydrology around the project site including TBM sections will occur.<br>- Since a river flow along the south of the depot candidate site, the depot construction may affect the surrounding hydrology. |
| | | | | | | | **OS:** Operation of the Metro may not cause any impact on surrounding hydrology. |
| | 11 | Geology and Topography | ✔ | ✔ | D | D | **CS/OS:** There is no specified and valuable geology and topography in and around the alignment. It was not observed any risks of slope collation and soil erosion in the proposed site for the depot. Also, the depot is designed as the structure of retaining wall instead of slope structure which can cause soil erosion in some situations. |
| Social Environment | 12 | Land acquisition/ Resettlement | ✔ | ✔ | A- | D | **Pre-CS / CS:** Resettlement in some areas in elevated areas have been started and structures have been resettled already (84 households) and 62 households are remaining as of July 2022. Besides the physical relocation, private Land acquisition and resettlement is required. Project-affected households is going to take impact on their property and livelihood. |
| | | | | | | | **OS:** Economic displacement may be occurred due to the Metro operation. But according to the SIA report 2022,<br>- The livelihood of the title holder PAHs will suffer little negative impact because they receive 212 percent price of minimum market value for their loss of land and assets.<br>- The non-title holder PAHs will find new locations for residences and commercial activities in adjacent areas in Patna metro area, and they will be eligible for compensations for loss of assets and various additional assistances for livelihood rehabilitation. It is assumed, therefore, that there will be little negative impact on the livelihood of the non-title holder PAHs after resettlement. |

| Category | No. | Impact Item | Evaluation | | | | Reason for evaluation |
|---|---|---|---|---|---|---|---|
| | | | Scoping | | Based on Survey | | |
| | | | Pre-CS/CS | OS | Pre-CS/CS | OS | |
| Social Environment | 13 | Poverty | ✔ | | A- | D | **Pre-CS:** Households under the poverty line living in the project affected areas (7 families) are affected due to resettlement. |
| | | | | | | | **OS:** Since there is no land acquisition and resettlement during the operation phase, operation activities that have a negative impact on people with poor class are not expected. |
| | 14 | Indigenous and ethnic people | ✔ | | D | D | **Pre-CS and CS:** Indigenous people was not observed in the project affected areas based on a survey on private land by the provincial government as well as past statistical data. |
| | | | | | | | **OS:** No impact is expected with the reasons same as the case of Pre-CS and CS. |
| | 15 | Local economy such as employment and livelihood, etc. | ✔ | | B± | B± | **Pre-CS and CS:**<br>- New employment and job opportunity may be created with the construction of Patna Metro.<br>- A negative impact on the livelihood of PAPs may be generated depending on land acquisition and resettlement including business loss due to loss of access by fencing works around the construction areas. |
| | | | | | | | **OS:**<br>- New employment may be created with the opening of Patna Metro.<br>- A positive impact for the local economy will be generated such as timesaving for traveling within Patna city and alleviation of traffic congestion.<br>- With the opening of Patna Metro, drivers of route buses and three wheelers, which are overlapping their operation area of transportation, may lose their opportunities. However, positive expectation were observed because they can find another function such as feeder transportation between Patna Metro stations and customers final destination. |
| | 16 | Land use and utilization of local resources | ✔ | ✔ | D | B- | **CS:** Construction work in the area will not bring any significant changes in the land use pattern. The development of station buildings will not have any major significant impact on the future land use. |
| | | | | | | | **OS:** There is no land acquisition and resettlement in the operation phase. However, negative impact may occur from disordered development and rough-and-tumbled utilization of local resources around the Corridors and stations. |
| | 17 | Water use and its rights | ✔ | | B- | D | **CS:** Land acquisition and construction work such as TBM method may affect drinking water sources such as wells. |
| | | | | | | | **OS:** There is no impact on water use because of no land acquisition in the operation phase. |
| | 18 | Existing social infrastructure and services | ✔ | | B- | B+ | **Pre-CS and CS:**<br>- A negative impact on sensitive facilities such as schools, hospitals, and community centres may occur due to land acquisition and traffic issues such as congestion and accidents.<br>- The impact of the relocation of underground facilities is expected due to the construction work, which cause a temporal power outage in the surrounding area. |
| | | | | | | | **OS:** Improvement of accessibility by installing Patna Metro stations is expected, by which there is a possibility of a positive impact on the use of social infrastructure such as school, hospital, etc. |

| Category | No. | Impact Item | Evaluation | | | | Reason for evaluation |
|---|---|---|---|---|---|---|---|
| | | | Scoping | | Based on Survey | | |
| | | | Pre-CS/CS | OS | Pre-CS/CS | OS | |
| Social Environment | 19 | Maldistribution of benefit and damage | ✔ | ✔ | B- | D | **CS:** Depending on the construction area, there may be a maldistribution of benefit and damage such as the prohibition of road crossing and setting of the detour route. |
| | | | | | | | **OP:** Outstanding maldistribution of benefit is not expected. |
| | 20 | Local conflict of interest | ✔ | | B- | D | **CS:** - Residents and municipalities may demand that construction contractor should supply employment opportunities equally as construction workers.<br>- Pollution status may cause conflict along the construction affected areas |
| | | | | | | | **OP:** Outstanding impact on local conflict of interest is not expected. |
| | 21 | Cultural Heritage | ✔ | ✔ | D | D | **Pre-CS/CS:** No historical/ cultural monument will be affected as a result of the proposed development of project. Hence no prior permission is envisaged. |
| | | | | | | | **OS:** No historical/ cultural monument will be affected as a result of the proposed development of project. Hence no prior permission is envisaged. |
| | 22 | Landscape | | ✔ | D | D | **CS:** There is no landscape conservation area designated by law and regulation in the vicinity of the elevated section. |
| | | | | | | | **OS:** Since the construction is mainly conducted in the central part of the existing road and underground, there is no impact on landscape. |
| | 23 | Gender | ✔ | ✔ | B- | B- | **CS:** There may be a gender gap regarding wage, salary, and treatment as construction workers. |
| | | | | | | | **OS:** - Employment opportunities for women will be limited concerning Metro operation.<br>- Female passengers may give up getting on a train because of being afraid of congestion on the train during commuting time. |
| | 24 | Children's right | ✔ | | B- | D | **CS:** - There might be a possibility of child labour in construction sites.<br>- Construction work may interfere with going to educational facilities. |
| | | | | | | | **OS:** There is no impact on children's rights by Patna Metro operation. |
| | 25 | Health (Infectious diseases such as HIV/AIDS, etc.) | ✔ | ✔ | B- | B- | **CS:** Infectious diseases such as HIV/AIDS, COVID-19, etc. may be spread by the inflow of construction workers. |
| | | | | | | | **OS:** Infection of COVID-19 may occur in the train due to three Cs (closed spaces, crowded places, and close-contact settings) if the epidemic continues until the operation phase. |
| | 26 | Labor environment including labor safety | ✔ | ✔ | B- | D | **CS:** Occupational injuries / disease may occur with inappropriate labor environment including safety management in the construction sites, such as working on high structures and in underground spaces. |
| | | | | | | | **OS:** There is no big change in the labor environment for residents by Patna Metro operation. |

| Category | No. | Impact Item | Evaluation | | | | Reason for evaluation |
|---|---|---|---|---|---|---|---|
| | | | Scoping | | Based on Survey | | |
| | | | Pre-CS/CS | OS | Pre-CS/CS | OS | |
| Others | 27 | Accidents | ✔ | ✔ | B- | D | **CS:** - Since construction-related vehicles use arterial roads on the Patna Metro Corridors, there is a possibility of increasing traffic accidents.<br>- Detour and caused traffic congestions may increase the number of traffic accidents. |
| | | | | | | | **OS:** Outstanding and direct impact on traffic accident due to the Metro operation is not expected. |
| | 28 | Cross-border impact and climate change | ✔ | ✔ | B- | B± | **CS:** Greenhouse gas emissions will increase by reducing the absorbed amount of greenhouse gas by cutting street trees along the alignment, operation of construction heavy machinery, and construction of structures. |
| | | | | | | | **OS:** - Since the traffic volume along the Corridors will reduce due to Patna Metro operation, the reduction of greenhouse gases can be expected.<br>- It is conceivable that greenhouse gases will be generated due to the electric consumption by Patna Metro operation. |

Pre-CS: Pre-Construction Stage, CS: Construction Stage, OS: Operation Stage
A+/-: Significant positive/negative impact is expected, B+/-: Positive/Negative impact is expected to some extent, D: No impact is expected

Source: JST

## 14.8 Environmental Management Plan

### 14.8.1 Retroactive verification of EMP for the section under construction

The Patna Metro construction project has already been commenced partially in the section of both corridors. PMRCL prepared its own Environmental Management Plan (EMP) for the section in prior to the construction commencement and is following and implementing the EMP shown below. The EMP are set for a wide range of environmental and social items during construction, but it does not cover all designated items by the JICA guidelines, especially social consideration items: Existing social infrastructure and services, Gender, Local conflict of interest etc. Regarding these social consideration items, currently there are no particular issues due to the ongoing construction work, but complaints from local people about dust and traffic congestion etc. have been confirmed. Therefore, PMRCL shall be requested thorough compliance with EMP prepared by JST. Regarding the operation phase, the EMP is limited to noise, vibration and water quality, it is considered insufficient. Therefore, PMRCL shall follow the EMP prepared by JST.

**Table 14-54: Environmental Management Plan prepared by PMRCL**

| Environmental Impact item | Mitigation Measures Taken or to Be Taken | Time Frame | Implementation Body | Responsibility Body |
|---|---|---|---|---|
| **DESIGN PHASE** | | | | |
| Metro Alignment | The proposed corridor alignment was selected to minimize the landdisturbance to avoid environmentally sensitive areas. | DuringDesign | DPR and design consultant | PMRC/DMRC |
| Cultural Heritage | Avoided by adjustment of alignment. | During Design | DPR and design consultant | PMRC/ DMRC |
| Flood | Bridges shall be well designed | During Design | DPR and design consultant | PMRC/ DMRC |
| Inadequate design provision forsafety against seismological hazard | Make sure that design provides for safety of structures against worst combination of forces in the probability of an earthquake likely to occur in seismic zone-IV. | DPR and detailed design stage | DPR and design consultant | PMRC/ DMRC |
| **PRE –CONSTRUCTION STAGE** | | | | |
| Water requirement | The requirement of water for construction purpose etc. shall be planned and shall be arranged from available and authorized sources in order to avoid digging of Tube wells. | Pre-construction stage | Contractor | PMRC/EMP implementing agency |
| Disposal of final treated effluent from treatment plant | Options for final disposal shall bestudied and the suitable disposal route shall be decided carefully to minimize the impact on receiving bodies. As far as possible zero discharge rules may be adopted. | During design stage/ and pre-construction of treatment plant | Contractor | PMRC/EMP implementing agency |
| Batching Plant and Casting Yard | These facilities to be located away from habitation. Consent to Establish and Consent to Operate to be taken from PCB and to comply with all stipulations. | During Pre-construction Stage | Contractor | PMRC/EMP implementing agency |
| **CONSTRUCTION PHASE** | | | | |
| Environmental Management and Monitoring | This will include institutional requirements, training, environmental management and monitoring | During and after construction | Contractor | PMRC/EMP implementing agency |

| Environmental Impact item | Mitigation Measures Taken or to Be Taken | Time Frame | Implementation Body | Responsibility Body |
|---|---|---|---|---|
| Dust | Water should be sprayed during the construction phase, wherever it is required to avoid dust.<br>Vehicles delivering materials should be covered to reduce spills and dust blowing off the load. | During construction | Contractor | PMRC/EMP implementing agency |
| Air Pollution | Vehicles and machinery are to beregularly maintained so that emissions conform to National and State AAQ Standards. No vehicle without valid PUC certificate would be allowed at Construction Sites. | Beginning with and continuing throughout construction period | Contractor | PMRC/EMP implementing agency |
| Equipment Selection maintenance and operation | Construction plants and equipment will meet acceptable standards for emissions and will be maintained and operated in a manner that ensures that relevant air, noise, and discharge regulations are met. | During construction | Contractor | PMRC/EMP implementing agency |
| Noise | Noise standard at processing sites, willbe strictly enforced as per GOI noise standards. Workers in vicinity of strong noise will wear earplugs and their working time should be limited as a safety measure. At construction sites within 150m of sensitive receptors construction will be stoppedfrom 22:00 to 06:00.<br>Machinery to be provided noise barriers (Stone walls and plantation) for silence zones including schools and hospitals. | Beginning and through construction | Contractor | PMRC/EMP implementing agency |
| Vibration | The vibration level limits at work sites adjacent to the alignment shall conform to the permitted values of peak velocity as given in Environmental Manual | Beginning and through construction | Contractor | PMRC/EMP implementing agency |
| **WATER** | | | | |
| Contamination from Wastes | All justifiable measures will be takento prevent the wastewater produced in construction from entering directly into any rivers, drainage and irrigation system | Throughout construction period | Contractor | PMRC/EMP implementing agency |
| Wastage of water | Measures shall be taken to avoidmisuse of water. Construction agency shall be instructed accordingly to follow strict procedures while using the water for construction and drinking purpose. | Beginning with and continuing throughout construction | Contractor | PMRC/EMP implementing agency |
| Sewerage disposal duringconstruction at Service Centers | A minimum distance of any sewage or toilet facility from water sources should be 200 meters. | Throughout construction period | Contractor | PMRC/EMP implementing agency |
| Sanitation and Waste Disposal in Construction Camps | Sufficient measures will be taken in the construction camps, i.e. provision of garbage tank and sanitation facilities. Waste in septic tanks will be resettled periodically.<br>Drinking water will meet Indian National Standards.<br>Garbage will be collected in a tank and disposed of daily. Special attention shall be paid to the sanitary condition of camps.<br>Camps will be located at a minimum distance of 200 m from water sources. | Before and during building of construction camps | Contractor | PMRC/ EMP implementing agency |

| Environmental Impact item | Mitigation Measures Taken or to Be Taken | Time Frame | Implementation Body | Responsibility Body |
|---|---|---|---|---|
| **SOIL** | | | | |
| Quarrying | Quarrying will be carried out at approved and licensed quarries only. All environmental mitigation measures shall be enforced at Quarry site also. | During construction | Contractor | PMRC/EMP implementing agency |
| **FLORA AND FAUNA** | | | | |
| Loss of treesand AvenuePlantation | Areas of tree plantation resettled will be replaced according to Compensatory Afforestation Policy under the Forest Conservation Act. Four trees will be planted against every tree felled as per norms. | During and after completion of construction activities | PMC | PMC/ PMRC |
| **SOCIAL** | | | | |
| Loss of Access | Temporary access should be built at the interchange and other roads. | During construction | Contractor | PMRC/ Traffic department |
| Traffic jams and congestion | If there are traffic jams during construction, measures should betaken to relieve the congestion with the co-ordination of transportation and traffic police department | During construction | Contractor | PMRC/ Traffic department |
| Safety with vehicles, people and Livestock and signage | Safety education and fines.<br>Allow for adequate traffic flow around construction areas.<br>Provide adequate signage, barriers and flag persons for safety precautions.<br>Communicate to the public through radio, TV & newspaper announcements regarding the scope and timeframe of projects, as well as certain construction activities causing disruptions or access restrictions | During construction | Contractor | PMRC/ Traffic department |
| Increase indisease Water-borne Insect-borne Communicable diseases | Make certain that there is good drainage at all construction areas, to avoid creation of stagnant water bodies.<br>Provide adequate sanitation and waste disposal at construction camps. Provide adequate health care for workers and locate camps away from vulnerable groups, if any | During construction At start-up Throughout construction | Contractor | PMRC/EMP implementing agency |
| Location ofcamps depotsand storage areas | Location of camps depots and storage areas shall be as per the contract specifications. | Throughout construction | Contractor | PMRC/EMP implementing agency |
| **OPERATION PHASE** | | | | |
| Noise and Vibration | Suitable measures should be considered where warranted. The public shall be educated about the regulations of noise and vibration pollution and its implications. | After completion of construction | PMRC/EMP implementing agency | PMRC/EMP implementing agency |
| **WATER** | | | | |
| Maintenance of Storm Water Drainage System | The urban drainage systems will be periodically checked and resettled so as to ensure adequate storm water flow. | Beginning and end of monsoon | PMRC/EMP implementing agency | PMRC/EMP implementing agency |

Source: DPR

The following photos illustrate current mitigation and monitoring practices. PMRCL has taken measures to deal with dust and traffic congestion, which are the most common complaints from local residents, but since further complaints are still delivered by local residents, it is necessary to analyze the complaints and focus on spot areas to address them.

**Table 14-55: Implementation status of Environment Management Plan**

| | |
|---|---|
|  |  |
| Use of nozzle-based mist system for dust suppression | Water sprinkling in dry season |
|  |  |
| Dust collector in batching plant | Wheel washing facility |
|  |  |
| Covering of conveyor belt | Covering of dry soil/sand at site |

| | |
|---|---|
|  |  |
| Use of bio toilet at site | Top soil conservation at Moin ul Haque stadium |
|  |  |
| Regular noise monitoring | Use of silent Diesel Generator set with appropriate stack height |
|  |  |
| Recycle of C & D waste for making flower pot | Recycle of fly ash for making bricks |




Use of color coded dust bin for waste segregation




Hazardous waste storage




Traffic Diversion works



Morning gathering, differentiate positions and responsibilities by the helmet color

Source: Monthly Progress Report Patna Metro Rail Project, PMRCL
Environmental Management Plan for the section to be constructed

EMP including mitigation measures has been prepared negative or potentially negative impacts mentioned so that it should be examined for respective project stages so that the project can achieve the intended objectives while minimizing accompanied environmental and social negative impacts. The costs, for mitigation measures and their implementation, are also included as follows.

The below table shows a preliminary set of mitigation measures for the impact items evaluated “A-” or “B-” in the matrix of Results of Assessment as above mentioned.

**Table 14-56: Proposed Mitigation Measures against expected Impacts (Pre-Construction or Construction Phase)**

| No. | Item | Expected Impact | Mitigation Measure | Implementation Body | Responsibility Body | Cost (INR) |
|---|---|---|---|---|---|---|
| 1-a | Air pollution | Emission gas (NOx, SOx) and dust (PM) will have a temporary negative impact on the air quality by construction machineries and vehicles. | Regular preventive maintenance service of construction equipment and machinery should be strictly implemented and should require conducting daily routine equipment and machinery check-ups to ensure that there are in optimum working conditions. | Construction Contractor | PIU | Mentioned in EMoP |
| 1-b | | | The proper work schedules should be considered not to concentrate the construction equipment at a certain point for a long time. | | | |
| 1-c | | | To reduce the dust, the periodic water spray should be taken. | | | |
| 1-d | | | The construction site is fenced as high as 2-2.5 m. | | | |
| 2-a | Water pollution | • Turbid water will be generated in surface water and groundwater along the Corridors due to civil and excavation works.<br>• Turbid water will be generated at a proposed site for depot due to soil filling works.<br>• There is a possibility of discharged organic waste water at an installed base campsite. | Washing the construction tools in limited areas where there are appropriate facilities for water treatment for discharge | Construction Contractor | PIU | Mentioned in EMoP |
| 2-b | | | Construction waste should be treated at a designated site and disposed of following the instruction of management authority and rules. If the waste must be kept at the construction site, the tarpaulin should be covered on it. | | | |
| 2-c | | | In construction works near water bodies, turbid waste water shall be treated at designated sites and released again. | | | |
| 2-d | | | Temporary sanitation facilities with septic tanks such as portable (mobile) toilets and garbage bins will be provided by the contractors to ensure that the domestic wastes to be generated by the construction personals are properly handled and not thrown into the drainage to prevent further pollution. | | | |
| 3-a | Waste | • General waste and excreta will be generated from the base campsite.<br>• Construction waste such as soil and deforestation trees are generated.<br>• Muck due to tunnel excavation is generated. | Construction waste generated from the construction and camp sites should be treated at a designated site and disposed of according to the instructions of management authority and rules. If the waste must be kept at the construction site, the tarpaulin should be covered on it. | Construction Contractor | PIU | Mentioned in EMoP |
| 3-b | | | Generated waste could be utilized for other purpose such as land filling depending upon the suitability. | | | |
| 4-a | Soil contamination | • Excavated soil at the construction site may be contaminated.<br>• Oil leaks from constriction equipment may cause soil contamination. | Excavated soil shall be treated at the designated site and disposed of following the instruction of management authority and rules. If the waste must be kept at the construction site, the tarpaulin should be covered on it. | Construction Contractor | PIU | Mentioned in EMoP |
| 4-b | | | Daily maintenance of construction equipment and vehicles. | | | |
| 4-c | | | Soil sampling and laboratory analysis in order to check soil contamination shall be done. | | | |

| No. | Item | Expected Impact | Mitigation Measure | Implementation Body | Responsibility Body | Cost (INR) |
|---|---|---|---|---|---|---|
| 5-a | Noise and vibration | Noise and vibration will be generated by construction machineries and vehicles. | Noise suppressors such as mufflers will be installed whenever deemed necessary to maintain the noise generated by various heavy equipment and other construction machinery within permissible limits. | Construction Contractor | PIU | Mentioned in EMoP |
| 5-b | | | High noise-generating construction activities will be scheduled during daytime only (8:00 - 20:00) to avoid noise disturbance to adjust residential and commercial areas and other noise-sensitive areas. In the case of academic facilities, the activities should be considered during the night time not to interfere with the class-works. | | | |
| 5-c | | | Around the construction site is fenced as high as 2-2.5 m. | | | |
| 5-d | | | Use low-noise and vibration machinery for construction such as piling | | | |
| 5-e | | | If cracks, fissures, etc. occur in the surrounding structures during the construction of the underground section, the repair of such cracks, fissures, etc. shall be covered by the compensation. | | | |
| 6-a | Ground subsidence | There is a possibility of ground subsidence in case of the soft foundation under the elevated section, depot area and underground construction sections including stations. | Application of appropriate construction measures such as earth retaining wall, penetration of piles to the support layer, and etc. | Construction Contractor | PIU | Mentioned in EMoP |
| 6-b | | | Application of ground reinforcement measures such as sand pile method to the soft-ground areas, if any. | | | |
| 7 | Offensive odor | Offensive odor may be issued depending on the volume of general waste, etc. from base camp sites. | Regular cleaning and collection of the general waste from camp sites with appropriate stock places and facilities to prevent offensive odor. | Construction Contractor | PIU | Mentioned in EMoP |
| 8 | Protected Area | Although Sanjay Gandhi Botanical Park (SGB Park or Patna Zoo) is designated as a protected area, it is managed by the Government of Bihar as Park-cum-Zoo, whose management type is different from that of other natural protected areas which has a development risk of disorderly destruction. However, the area may have ecological functions in the urban environment of Patna. Therefore, general considerations to mitigate impacts from the project regarding pollution items shall be taken. | Same as "5. Noise and vibration". | Construction Contractor | PIU | Mentioned in EMoP |

| No. | Item | Expected Impact | Mitigation Measure | Implementation Body | Responsibility Body | Cost (INR) |
|---|---|---|---|---|---|---|
| 9-a | Ecosystem | • There is a negative impact on the ecosystem through the deforestation of trees due to the construction of viaducts, underground stations and a depot.<br>• Since a partial section pass through Danapur Cantonment KBA, the impact on ecosystem, especially on avifaunal diversity, such as light pollution, noise and vibration are expected. | Compensatory planting of street trees / shrubbery species to the limited area under the elevated structures should be considered as necessary. | Construction Contractor | PIU | Mentioned in EMoP |
| 9-b | | | A preliminary survey should be conducted before the construction commencement and during construction in order to confirmation of nesting and flying in the project site of KBA area. Countermeasures such as avoidance of construction during their breeding season should be considered if nesting or flying of the specified species is confirmed in the project area. | | | |
| 9-c | | | Reduction of noise pollution during night hours and within standards. | | | |
| 9-d | | | Reduction of light pollution during night hours by keeping lights close to the ground, directed and shielded. | | | |
| 10-a | Hydrology | Some impact on hydrology around the project site including TBM sections will occur. Since a river flow along the south of the depot candidate site, the depot construction may affect the surrounding hydrology. | Sheet pile should be installed at the excavation work site in order to water sealing. | Construction Contractor | PIU | Mentioned in EMoP |
| 10-b | | | Closed mold type of TBM should be used in order to keep groundwater pressure. | | | |
| 10-c | | | Groundwater monitoring using construction well. | | | |
| 10-d | | | Perforated sheet pile should be installed at the Depot construction site in order to keep groundwater flow. | | | |
| 11-a | Land acquisition/ Resettlement | • Resettlement in some areas in elevated areas have been started and structures have been resettled already (84 households) and 62 households are remaining as of July 2022. Besides the physical relocation, private land acquisition is required. Such project - affected households is going to take impact on their property and livelihood.<br>• Follow-up actions against pre-relocated households before the official approval of RAP equivalent documents | Resettlement implementation with necessary procedures based on RAP (SIA Report) including:<br>- Compensation prior to relocation with full replacement cost<br>- Functioning of grievance redress mechanism<br>- Livelihood restoration program<br>- Monitoring schemes<br>- Special assistance to vulnerable groups, etc. | PIU | Government of Bihar | Refer to SIA |
| 11-b | | | Action plan (follow-up activities) to fulfill gaps between the conditions of pre-relocation cases and the one equivalent to the JICA Guidelines. | | | |
| 12 | Poverty | Households under poverty line living in the project affected areas (7 families) are affected due to resettlement. | Implementation of adequate compensation and assistance based on the entitlement matrix of RAP (SIA) and/or any other follow-up documents, if any | PIU | Government of Bihar | Refer to SIA |

| No. | Item | Expected Impact | Mitigation Measure | Implementation Body | Responsibility Body | Cost (INR) |
|---|---|---|---|---|---|---|
| 13-a | Local economy such as employment and livelihood, etc. | A negative impact on the livelihood of PAPs may be generated depending on land acquisition and resettlement including business loss due to loss of access by fencing works around the construction areas. | Implementation of adequate compensation and assistance based on the livelihood restoration program of RAP (SIA) and/or any other follow-up documents, if any | PIU | Government of Bihar | Refer to SIA |
| 13-b | | | Compensation for any business disturbance during the construction including hindrance of access to shops due to fencing around the construction sites. | | | |
| 14 | Water use and its rights | Land acquisition and construction work such as TBM method may affect drinking water sources such as wells. | If the water quality deems to decline, appropriate water treatment measures such as water shielding and infiltration control should be implemented. | Construction Contractor | PIU | Mentioned in EMoP |
| 15-a | Existing social infrastructure and services | • A negative impact on sensitive facilities such as schools, hospitals, and community centers may be occurred depending on land acquisition and traffic issues such as congestion and accidents.<br>• The impact of the relocation of underground facilities is expected due to the construction work, which cause a temporal power outage in the surrounding area. | Make sure to provide electrical power by auxiliary grid or generators to keep providing it. Therefore, a detailed power distribution plan should be prepared in advance. | Construction Contractor | PIU | Mentioned in EMoP |
| 15-b | | | Make sure to provide safe access to sensitive facilities such as hospital, school, etc. during the construction period by installing traffic guides and warning signs, and if required, measures such as detour route should be set up based on the traffic congestion condition. | | | |
| 16 | Maldistribution of benefit and damage | Depending on the construction area, there may be a maldistribution of benefit and damage such as the prohibition of road crossing and setting of the detour route. | Make sure to provide safe access to sensitive facilities such as hospitals, schools, etc. during the construction period by installing traffic guides and warning signs, and if required, measures such as detour route should be set up based on the traffic congestion condition. | Construction Contractor | PIU | Mentioned in EMoP |
| 17-a | Local conflict of interest | • Residents and municipalities may demand that construction contractor should supply employment opportunities equally as construction workers.<br>• Pollution status may cause conflict along the construction affected areas | Give employment opportunities to residents and municipalities evenly. | Construction Contractor | PIU | Mentioned in EMoP |
| 17-b | | | If the residents and pedestrians complain about the construction activities, the consultant of the supervision and contractors should deal with them with a sincere response following the Grievance Redress mechanism and should designate staff in charge of public complaints and communications. | | | |
| 18 | Gender | There may be a gender gap regarding wage, salary, and treatment as construction workers. | There must be care that there is no discrimination between male and female in employment and payment of wages/salaries. | Construction Contractor | PIU | Mentioned in EMoP |

| No. | Item | Expected Impact | Mitigation Measure | Implementation Body | Responsibility Body | Cost (INR) |
|---|---|---|---|---|---|---|
| 19-a | Children's right | There might be a possibility of child labour in construction sites. | Construction contractor and supervision consultant as well as PIU check and monitor the list or worker and field situation in order to prevent any forms of child labor in the project. | Construction Contractor | PIU | Mentioned in EMoP |
| 19-b | | Construction work may interfere with going to educational facilities. | Same as "15-b" | | | |
| 20-a | Health (Infectious diseases such as HIV/AIDS, etc.) | Infectious diseases such as STD, COVID-19, etc. may be spread by the inflow of construction workers. | To prevent the spreading of infectious diseases, awareness training to workers shall be provided with the cooperation of the local public health center. | Construction Contractor | PIU | Mentioned in EMoP |
| 20-b | | | A periodic health check-up program will be conducted. | | | |
| 20-c | | | To reduce ponds and puddles, where wrigglers grow, by covering them with a tarpaulin. | | | |
| 20-d | | | [Countermeasures for COVID-19]<br>• Keep physical distance<br>• Washing hands and alcohol disinfection<br>• Body temperature test before morning gathering | | | |
| 21-a | Labor environment including labor safety | Occupational injuries / disease may occur with inappropriate labor environment including safety management in the construction sites, such as working on high structures and in underground spaces. | Construction personnel will be provided with the necessary safety gear such as a protective hard hat and safety belt. | Construction Contractor | PIU | Mentioned in EMoP |
| 21-b | | | First aid stations supervised by the safety health officer of the contractor will be located within the construction site office. | | | |
| 21-c | | | Arrange safety training for the worker periodically. | | | |
| 21-d | | | Compliance with the related laws and regulations. | | | |
| 22-a | Accidents | • Since construction-related vehicles use arterial roads on the Corridors, there is a possibility of increasing traffic accidents.<br>• Detour and caused traffic congestions may increase the number of traffic accidents. | Sound traffic management and detour plans duly approved by the concerned governmental agency will be strictly implemented to minimize traffic congestions and accidents. | Construction Contractor | PIU | Mentioned in EMoP |
| 22-b | | | Traffic enforcers will be designated along these areas to assist in directing traffic flow. | | | |
| 23 | Cross-border impact and climate change | Greenhouse gas emissions will increase slightly by reducing the absorbed amount of greenhouse gas by cutting street trees along the Corridors, operation of construction heavy machinery, and construction of structures. | Planting of shrubbery spices to the limited area under the elevated structures should be considered as necessary to reduce the emission of greenhouse gases. | Construction Contractor | PIU | Mentioned in EMoP |

Note: PIU: Project Implementation Unit

Source: JST

**Table 14-57: Proposed Mitigation Measures against expected Impacts (Operation Phase)**

| No. | Item | Expected Impact | Mitigation Measure | Implementation Body | Responsibility Body | Cost (INR) |
|---|---|---|---|---|---|---|
| 1 | Air pollution | Pollutant concentration may be occurred around the ventilation facilities in the underground sections and substations. | Periodical maintenance of relevant facilities such as ventilation system, substation, and the depot. | PMRCL | Government of Bihar | Mentioned in EMoP |
| 2 | Water pollution | There is a possibility of discharged organic waste water from the toilet installed at every station and the depot. | Periodical maintenance of relevant facilities such as toilet installed at every station and the depot. | PMRCL | Government of Bihar | Mentioned in EMoP |
| 3 | Waste | General waste and excreta will be generated from every station and the depot. | Installation of enough garbage bin at appropriate location in stations and the depot and collection rules based on local collection systems. | PMRCL | Government of Bihar | Mentioned in EMoP |
| 4-a | Soil contamination | Soil contamination may occur at a depot due to oil leaks of related facilities, rolling stock coating. | Necessary facilities and equipment for preventing leaking oil shall be prepared at the depot and the receiving substations. | PMRCL | Government of Bihar | Mentioned in EMoP |
| 4-b | | Inappropriate management of transformer will cause oil leakage. Consequently, it will contaminate the soil. | Regular preventive maintenance service of transformer should be strictly implemented | | | |
| 5-a | Noise and vibration | Metro rail may generate additional noise and vibration by itself in both underground and elevated sections. | Additional noise barriers are discussed, as needed | PMRCL | Government of Bihar | Mentioned in EMoP |
| 5-b | | | At the station platform, paging and train melody volume shall be adjusted to the lowest level where it will not detract from their function. | | | |
| 5-c | | | Slow speed in curve sections | | | |
| 6 | Ground Subsidence | Monitoring in the operation phase should be necessary as a follow-up observation and maintenance. | No specific measures but conduct necessary monitoring for "just in case". When measures are need, they are to be discussed to determine the best solution suitable for the conditions. | PMRCL | Government of Bihar | Mentioned in EMoP |
| 7-a | Offensive odor | Offensive odor may be issued depending on the volume of general waste etc. from every station and the depot. | Regular cleaning and collection of the general waste from stations and depot. | PMRCL | Government of Bihar | Mentioned in EMoP |
| 7-b | | | Installation of appropriate garbage bin with cover. | | | |
| 8 | Ecosystem | Since a partial section pass through Danapur Cantonment KBA, the impact on ecosystem, especially on avifaunal diversity, such as light pollution is expected. | Reduction of light pollution during night hours by keeping lights directed and shielded. | PMRCL | Government of Bihar | Mentioned in EMoP |

| No. | Item | Expected Impact | Mitigation Measure | Implementation Body | Responsibility Body | Cost (INR) |
|---|---|---|---|---|---|---|
| 9 | Local economy such as employment and livelihood, etc. | With opening of Patna Metro, drivers of route buses and three wheelers, which are overlapping their operation area of transportation, may lose their opportunities. | Monitoring impact on drivers of bus, three wheeler, and other alternative transportation around the Metro. Livelihood assistance or job meditation including the Metro related opportunities. | Government of Bihar | Government of Bihar | Mentioned in EMoP |
| 10 | Land use and utilization of local resources | A negative impact may be generated as disordered development and rough-and-tumbled utilization of local resources around the Corridors and stations. | Coordination with local government and private developers for healthy socio-economic development along the Metro lines. | Government of Bihar | Government of Bihar | Mentioned in EMoP |
| 11-a | Gender | • Employment opportunities for women will be limited concerning Metro operation.<br>• Female passengers may give up getting on a train because of being afraid of congestion on the train during commuting time. | Active employment of female staff for PMRCL with fair conditions | PMRCL | Government of Bihar | Mentioned in EMoP |
| 11-b | | | Keep provision of the designated seat for women on the train, enough number of toilet and other facilities as much as possible. | | Government of Bihar | |
| 12-a | Health (Infectious diseases such as HIV/AIDS, etc.) | Infectious of COVID-19 may occur in the train due to three Cs (closed spaces, crowded places, and close-contact settings) if the epidemic continues until the operation phase. | A periodic awareness program for the PMRCL officials | PMRCL | Government of Bihar | Mentioned in EMoP |
| 12-b | | | A periodic health check-up program for the PMRCL officials | | | |
| 12-c | | | [Countermeasures for COVID-19]<br>• Air circulation in the train by air conditioning<br>• Cleaning rolling stocks periodically<br>• Opening the windows in the train<br>• Promotion of staggered working hours<br>• Installation of disinfectants at every toilet and ticket gate | | | |
| 13 | Cross- border impact and climate change | It is conceivable that greenhouse gases will be generated due to the electric consumption by Patna Metro operation. | Periodical maintenance of relevant facilities such as ventilation system, substation, and the depot. | PMRCL | Government of Bihar | Mentioned in EMoP |

Note: PIU: Project Implementation Unit

Source: JST

## 14.9 Environmental Monitoring Plan

### 14.9.1 Retroactive verification of EMoP for the section under construction

Same as EMP, PMRCL prepared their own Environmental Monitoring Plan (EMoP) for the section under construction in prior to the construction commencement and is following and implementing the EMoP shown below. However, the EMoP are set for the limited environmental items at construction phase and operation phase, especially ecosystem and social consideration items: Existing social infrastructure and services, Gender, Local conflict of interest etc. Regarding these items, currently there are no particular issues due to the ongoing construction work, or no endangered species under the ongoing construction sections. But complaints from local people about dust and traffic congestion etc. have been confirmed. Given the above, it cannot be said that EMoP can cover all designated items by the JICA guidelines. Hence, PMRCL shall follow the EMoP prepared by JST.

According to the monitoring result of air quality and noise, the values of all of the parameter at all point were lower than the baseline ones. It can be said that the traffic impact is larger than the impact from construction. Especially, since the values of construction noise level in daytime at almost points are about 10 dB lower than the baseline noise level, it can be said that the construction noise hardly contributes to the increase of baseline noise. The details of monitoring result at the sections under construction are attached as an Attachment 13.

**Table 14-58: Environmental Monitoring Plan prepared by PMRCL**

| Environmental Impact item | Number of sampling, contents etc. | Implementation Body | Responsible Body |
|---|---|---|---|
| **Pre-construction phase** | | | |
| Air quality | 2 samples each at 9 locations | Contractor | PIU |
| Water quality | 1 sample each at 9 locations | Contractor | PIU |
| Noise and Vibration | Noise: 1 sample each at 9 locations<br>Vibration: 2hours each at 9 locations | Contractor | PIU |
| Soil quality | 1 sample each at 8 locations | Contractor | PIU |
| **Construction phase** | | | |
| Air quality | The parameters recommended are Particulate Matter ($PM_{10}$), ($PM_{2.5}$). The contractor will be responsible for carrying out air monitoring during the entire construction phase under the supervision of project authority. | Contractor | PIU |
| Water quality | Water quality should be analyzed following the procedures given in standard methods. Parameters for monitoring will be as per BIS: 10500:2012. The monitoring points could be ground and surface water. The contractor shall also monitor soil leachate monitoring. | Contractor | PIU |
| Noise and Vibration | The noise levels will be monitored at construction sites for entire phase of construction by the site contractor and under the supervision of project authority. At sensitive locations Vibration shall also be monitored as per the directions of the employer. | Contractor | PIU |
| Workers health and safety | Regular inspection and medical checkups shall be carried out to workers health and safety monitoring. Any reoccurring incidents such as irritations, rashes, respiratory problems etc. shall be recorded and appropriate mitigation measures shall be taken. Contractor will be the responsible person to take care health and safety of workers during the entire period of the construction and project proponent is responsible to review/audit the health and safety measures/plans. | Contractor | PIU |

| Environmental Impact item | Number of sampling, contents etc. | Implementation Body | Responsible Body |
|---|---|---|---|
| **Operation phase** | | | |
| Air quality | 1 sample each at 7 locations monthly for 3 years<br>The parameters recommended are Particulate Matter ($PM_{10}$), ($PM_{2.5}$). | PMRCL | Government of Bihar |
| Water quality | 1 sample yearly for 3 years<br>The parameters recommended are pH, TSS, BOD, COD, oil and grease for waste water, but water quality parameters that will be monitored will be as per BIS 10500:2012. | PMRCL | Government of Bihar |
| Noise and vibration | 1 sample each at 15 locations yearly for 3 years | PMRCL | Government of Bihar |

Note: PIU: Project Implementation Unit

Source: DPR

**Table 14-59: Example of air quality monitoring result**

| Date | Locations | $PM_{10}$ (µg/m$^3$) | | |
|---|---|---|---|---|
| | | Monitored value | Baseline Value | Air quality Standards |
| 03-Jun-22 | Bhootnath | **150.49** | **279.3** | 100 |
| 03-Jun-22 | Zero mile | **190** | **210.5** | |
| 04-Jun-22 | Malahi Pakri | **162.76** | **191.2** | |
| 04-Jun-22 | Khemni Chak | **154.04** | **191.3** | |
| 05-Jun-22 | New ISBT | **167.5** | **395.8** | |
| 14-Jun-22 | Bhootnath | **173.68** | **279.3** | |
| 14-Jun-22 | Zero mile | **197.32** | **210.5** | |
| 15-Jun-22 | Malahi Pakri | **148.52** | **191.2** | |
| 15-Jun-22 | Khemni Chak | **136** | **191.3** | |
| 16-Jun-22 | New ISBT | **178** | **395.8** | |

Source: PMRCL

**Table 14-60: Example of noise monitoring result**

| Date | Locations | Construction site Leq dB (A) | | Baseline Leq dB (A) | | Permissible limit Leq dB (A) | |
|---|---|---|---|---|---|---|---|
| | | Day | Night | Day | Night | | |
| 04-Jun-22 | Malahi Pakdi | 64.1 | **62.9** | **78.2** | **63.4** | 65 | 55 |
| 10-Jun-22 | | 63.6 | **60.3** | | | | |
| 15-Jun-22 | | 63.8 | **62.5** | | | | |
| 20-Jun-22 | | **67.2** | **60.0** | | | | |
| 04-Jun-22 | Khemni Chak | 64.1 | **63.1** | **73.7** | **63.2** | | |
| 10-Jun-22 | | 63.6 | **59.1** | | | | |
| 15-Jun-22 | | 63.8 | **61.3** | | | | |
| 20-Jun-22 | | **67.2** | **61.3** | | | | |
| 03-Jun-22 | Bhootnath | **71.3** | **63.0** | **82.0** | **73.0** | | |
| 09-Jun-22 | | **68.4** | **63.4** | | | | |
| 4-Jun-22 | | **69.2** | **64.1** | | | | |
| 19-Jun-22 | | **70.1** | **63.7** | | | | |
| 03-Jun-22 | Zero Mile | 62.0 | **60.9** | **75.0** | **63.0** | | |
| 09-Jun-22 | | **67.8** | **62.4** | | | | |
| 14-Jun-22 | | **66.3** | **62.8** | | | | |
| 19-Jun-22 | | **65.9** | **62.0** | | | | |
| 05-Jun-22 | New ISBT | **72.4** | **66.2** | **83.4** | **67.1** | | |
| 11-Jun-22 | | **66.7** | **63.0** | | | | |
| 16-Jun-22 | | **70.1** | **66.2** | | | | |
| 21-Jun-22 | | **71.9** | **65.8** | | | | |

Source: PMRCL

### 14.9.2 Environmental Monitoring Plan for the section to be constructed

Regarding the environmental and social consideration items for which the draft mitigation measures are set for Patna metro construction work, EMoPs to inspect the effect of the measures are shown as below.

**Table 14-61: Environmental Monitoring Plan (Pre-Construction and Construction Phase) proposed by the survey**

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 1-a | Air pollution | Regular preventive maintenance service of construction equipment and machinery should be strictly implemented and should require conducting daily routine equipment and machinery check-ups to ensure that there are in the optimum working conditions. | Sampling survey using the same methods as the baseline survey for $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$, CO, Ozone and any other necessary items | Construction Contractor | PIU | Measured points during the baseline surveys | Monthly during the construction period | 12,000/point |
| 1-b | | The proper work schedules should be considered not to concentrate the construction equipment at a certain point for a long time. | Construction plan / schedule | Construction Contractor | PIU | Whole construction area | | Included in construction cost |
| 1-c | | To reduce the dust, the periodical water spray should be taken. | Record of sprinkler truck operation | Construction Contractor | PIU | Whole construction area | | |
| 1-d | | Around the construction site is fenced as high as 2-2.5 m. | Visual confirmation of installation of fences | Construction Contractor | PIU | Whole construction area | Before commencement of construction | |
| 2-a | Water pollution | Washing the construction tools limited areas where there are appropriate facilities for water treatment for discharge | Visual confirmation of appropriate operation of washing activities | Construction Contractor | PIU | Washing areas | Monthly during the construction period | Included in construction cost |
| 2-b | | Construction waste should be treated at a designated site and disposed of following the instruction of management authority and rules. If the waste must be kept at the construction site, the tarpaulin should be covered on it. | Record of disposal / Visual confirmation | Construction Contractor | PIU | Designated sites | | |
| 2-c | | In construction works near water bodies, turbid waste water shall be treated at designated sites and released again. | Sampling survey using the same methods as the baseline survey:<br>[Surface water] | Construction Contractor | PIU | Measured points during the baseline surveys | | Ground water: 10,000/point |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 2-d | | Temporary sanitation facilities with septic tanks such as portable (mobile) toilets and garbage bins will be provided by the contractors to ensure that the domestic wastes to be generated by the construction personals are properly handled and not thrown into the drainage to prevent further pollution. | BOD, COD, DO, Colour, Odour, Taste, pH, Turbidity, Temperature, etc.<br>[Groundwater]<br>Colour, Odour, Taste, pH, Turbidity, Temperature, Total Hardness as $CaCO_3$, etc. | Construction Contractor | PIU | Measured points during the baseline surveys | | Surface water: 10,000/point |
| 3-a | Waste | Construction waste generated from the construction and camp sites should be treated at a designated site and disposed of according to the instructions of management authority and rules. If the waste must be kept at the construction site, the tarpaulin should be covered on it. | • The volume of waste including soil, vegetation, existing railway structures, and garbage<br>• The condition of storage and transportation for the generated waste<br>• Voices and complaints from the local community | Construction Contractor | PIU | Construction site and labor camps | Monthly and when complaints are heard in this regard | Included in construction cost |
| 3-b | | Generated waste could be utilized for other purpose such as land filling depending upon the suitability. | Soil / muck reuse plan and record of dumping | Construction Contractor | PIU | Project sites | Monthly during the construction period | |
| 4-a | Soil contamination | Excavated soil shall be treated at the designated site and disposed of following the instruction of management authority and rules. If the waste must be kept at the construction site, the tarpaulin should be covered on it. | Same as "3-a" | | | | | |
| 4-b | | Daily maintenance of construction equipment and vehicles. | Sampling survey using the same methods as the baseline survey pH, Electrical Conductivity, Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Cyanide (Cn) and Chromium ($Cr^{+6}$) | Construction Contractor | PIU | Measured points during the baseline surveys | Monthly during the construction period | Included in construction cost |
| 4-c | | Soil sampling and laboratory analysis in order to check soil contamination shall be done. | | | | | | 10,000/point |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 5-a | Noise and vibration | Noise suppressors such as mufflers will be installed whenever deemed necessary to maintain the noise generated by various heavy equipment and other construction machinery within permissible limits. | • Visual observation of installation of necessary facilities<br>• Record of construction work (operation time)<br>• Record of using machinery<br>• Same methods as the baseline survey<br>On weekday<br>[Noise] LAeq<br>[Vibration] Lv | Construction Contractor | PIU | Whole construction area<br>Measured points during the baseline surveys | Monthly during the construction period | Included in construction cost |
| 5-b | | High noise-generating construction activities will be scheduled during daytime only (8:00 - 20:00) to avoid noise disturbance to adjust residential and commercial areas and other noise-sensitive areas. But in the case of academic facilities, the activities should be considered during the night time not to interfere with the class-works. | | | | | | Noise and vibration: 70,000/point |
| 5-c | | Around the construction site is fenced as high as 2-2.5 m. | | | | | | Included in construction cost |
| 5-d | | Use low-noise and vibration machinery for construction such as piling | | | | | | |
| 5-e | | If cracks, fissures, etc. occur in the surrounding structures during the construction of the underground section, the repair of such cracks, fissures, etc. shall be covered by the compensation. | Same as "11. Land acquisition/ Resettlement" | | | | | |
| 6-a | Ground subsidence | Application of appropriate construction measures such as earth retaining wall, penetration of piles to the support layer, and etc. | • Measurement of control points Ground subsidence level by subsidence plate<br>• Necessary foundation works | Construction Contractor | PIU | Construction sites | Monthly during the construction period | Included in construction cost |
| 6-b | | Application of ground reinforcement measures such as sand pile method to the soft-ground areas, if any. | | | | | | |
| 7 | Offensive odor | Regular cleaning and collection of the general waste from camp sites with appropriate stock places and facilities to prevent offensive odor. | • Record and Site observation<br>• Confirmation of voices and complaints Odor | Construction Contractor | PIU | Construction sites, labor camps and the surrounding area | Monthly and when complaints are heard in this regard | Included in construction cost |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 8 | Protected Area | Same as "5. Noise and vibration". | | | | | | |
| 9-a | Ecosystem | Compensatory planting of street trees / shrubbery species to the limited area under the elevated structures should be considered as necessary. | Status of planting | Construction Contractor | PIU | Construction sites and the surrounding area | Before construction and monthly during the construction period | Included in construction cost |
| 9-b | | A preliminary survey should be conducted before the construction commencement and during construction in order to confirmation of nesting and flying in the project site of KBA area. Countermeasures such as avoidance of construction during their breeding season should be considered if nesting or flying of the specified species is confirmed in the project area. | Site inspection focusing on nesting and flying | | | Danapur Cantonment KBA | Before construction and monthly during the construction period, and weekly during their breeding season | 30,000/time |
| 9-c | | Reduction of noise pollution during night hours and within standards. | Same as "5. Noise and vibration". | | | | Monthly during nighttime construction | Included in construction cost |
| 9-d | | Reduction of light pollution during night hours by keeping lights close to the ground, directed and shielded. | Visual observation of implementation status | | | | | |
| 10-a | Hydrology | Sheet pile should be installed at the excavation work site in order to water sealing. | Visual observation of implementation status | Construction Contractor | PIU | Construction sites and the surrounding area | Monthly during the construction period | Included in construction cost |
| 10-b | | Closed mold type of TBM should be used in order to keep groundwater pressure. | | | | | | |
| 10-c | | Groundwater monitoring using construction well. | Measurement of groundwater level | | | | | |
| 10-d | | Perforated sheet pile should be installed at the Depot construction site in order to keep groundwater flow. | Visual observation of implementation status and surface water flow | | | Depot sites and the surrounding area | | |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 11-a | Land acquisition/ Resettlement | Resettlement implementation with necessary procedures based on RAP (SIA Report) including:<br>- Compensation prior to relocation with replacement cost<br>- Functioning of grievance redress mechanism<br>- Livelihood restoration program<br>- Monitoring schemes<br>- Special assistance to vulnerable groups, etc. | Progress of RAP implementation: information including followings will be collected using the monitoring format attached to SIA Chapter.<br>• Consultation meeting and/ or other means of communication with the PAPs<br>• Confirmation of records of payment<br>• Site observation<br>• Confirmation of voices and complaints State of provision/ payment of compensation and social assistance and resettlement<br>• Level of income and livelihood restoration of the PAPs<br>• State of the project site<br>• Voices and complaints from the PAPs<br>Due-Diligence of RAP implementation: external evaluation expert will implement mid-term and end-term monitoring. | Social Management Unit, PMRCL, in coordination with Patna District Administration, Government of Bihar | PIU | Project affected area and locations PAHs are relocated | Progress of RAP implementation : monthly, up to the final payment and relocation.<br><br>Due-Diligence of RAP implementation : mid-term and end-term of rap implementation | Refer to SIA Chapter |
| 11-b | | Action plan (follow-up activities) to fulfill gaps between the conditions of pre-relocation cases and the one equivalent to the JICA Guidelines. | | | | | | |
| 12 | Poverty | Implementation of adequate compensation and assistance based on the entitlement matrix of RAP (SIA) and/or any other follow-up documents, if any | Same as "11. Land acquisition/ Resettlement" | | | | | |
| 13-a | Local economy such as employment and livelihood, etc. | Implementation of adequate compensation and assistance based on the livelihood restoration program of RAP (SIA) and/or any other follow-up documents, if any | Same as "11. Land acquisition/ Resettlement" | | | | | |
| 13-b | | Compensation for any business disturbance during the construction including hindrance of access to shops due to fencing around the construction sites. | | | | | | |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 14 | Water use and its rights | If the water quality deems to be declined, appropriate water treatment measures such as water shielding and infiltration control should be implemented. | Same as "2. Water pollution" | | | | | |
| 15-a | Existing social infrastructure and services | Make sure to provide electrical power by auxiliary grid or generators to keep providing it. Therefore, a detailed power distribution plan should be prepared in advance. | • Record and site observation<br>• Confirmation of voices and complaints Status of electricity supply<br>• Voices and complaints from the local community | Construction Contractor with relevant bodies | PIU | Project affected area | Before construction commencement and when complaints are heard in this regard | Included in construction cost |
| 15-b | | Make sure to provide safe access to sensitive facilities such as hospital, school, etc. during the construction period by installing traffic guides and warning signs, and if required, measures such as detour route should be set up based on the traffic congestion condition. | • Record and site inspection<br>• Interviews with concerned organizations<br>• Confirmation of voices and complaints Safety of access roads to these sensitive facilities<br>• Status of installation of signs, etc.<br>• Traffic congestion<br>• Voices and complaints from the local community | Construction Contractor | PIU | Construction sites and the surrounding area | | |
| 16 | Maldistribution of benefit and damage | Make sure to provide safe access to sensitive facilities such as hospitals, schools, etc. during the construction period by installing traffic guides and warning signs, and if required, measures such as detour route should be set up based on the traffic congestion condition. | Same as "15-b" | | | | | |
| 17-a | Local conflict of interest | Give employment opportunities to residents and municipalities evenly. | • Verification of employment status<br>• Voices and complaints from the local community | Government of Bihar | PIU | Project affected area | When complaints are heard in this | Included in construction cost |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 17-b | | If the residents and pedestrians complain about the construction activities, the consultant of the supervision and contractors should deal with them with a sincere response following the Grievance Redress mechanism and should designate staff in charge of public complaints and communications. | Confirmation of voices and complaints from the residents and pedestrians | Government of Bihar<br>Construction Contractor | PIU | Construction sites | regard | |
| 18 | Gender | There must be care that there is no discrimination between male and female in employment and payment of wages/salaries. | Confirmation of equal pay for equal work based on the employment agreements.<br>(If inadequate documents are identified, provide guidance to the contractor and require improvements.) | Construction Contractor | PIU | Construction site | Before construction commencement and at the time of employment | Included in construction cost |
| 19-a | Children's right | Construction contractor and supervision consultant as well as PIU check and monitor the list or worker and field situation in order to prevent any forms of child labor in the project. | • Voices and complaints from the local community and the construction workers Existence of child labor<br>• Confirmation of the construction contract<br>• Site observation | Government of Bihar<br>Construction Contractor | PIU | Project affected area | Before construction commencement and at the time of employment | Included in construction cost |
| 19-b | | Make sure to provide safe access to sensitive facilities such as hospital, school, etc. during the construction period by installing traffic guides and warning signs, and if required, measures such as detour route should be set up based on the traffic congestion condition. | Same as "15-b" | | | | | |
| 20-a | Health (Infectious diseases such as HIV/AIDS, etc.) | To prevent the spreading of infectious diseases, awareness training to workers shall be provided with the cooperation of the local public health center. | • Confirmation of health checklist of the workers and preferably of the local community<br>• Interviews with concerned organizations<br>• Confirmation of voices and complaints | Construction Contractor | PIU | Construction sites and surrounding area | Monthly during the construction period | Included in construction cost |
| 20-b | | A periodic health check-up program will be conducted. | • Confirmation of health checklist of the workers and preferably of the | Government of Bihar | PIU | Construction sites and | Monthly and when | Included in construction |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 20-c | | To reduce ponds and puddles, where wrigglers grow, by covering them with a tarpaulin. | local community<br>• Interviews with concerned organizations<br>• Confirmation of voices and complaints<br>• Visual observation<br>• Confirmation of voices and complaint | Construction Contractor | | surrounding area | complaints are heard in this regard | cost |
| 20-d | | Countermeasures for COVID-19<br>• Keep physical distance<br>• Washing hands and alcohol disinfection<br>Body temperature test before morning gathering | Same as "20-a" and "20-b" | | | | | |
| 21-a | Labor environment including labor safety | Construction personnel will be provided with the necessary safety gear such as a protective hard hat and safety belt. | • Confirmation of accidents records<br>• Confirmation of health checklist of workers<br>• Medical checkup of workers<br>• Number of cases that suffered from heat strokes and other occupational health problems<br>• Voice and complaints from the workers | Government of Bihar<br>Construction Contractor | PIU | Construction sites and surrounding area | Monthly and when complaints are heard in this regard | Included in construction cost |
| 21-b | | First aid stations supervised by the safety health officer of the contractor will be located within the construction site office. | | | | | | |
| 21-c | | Arrange safety training for the worker periodically. | | | | | | |
| 21-d | | Compliance with the related laws and regulations. | | | | | | |
| 22-a | Accidents | Sound traffic management and detour plans duly approved by the concerned governmental agency will be strictly implemented to minimize traffic congestions and accidents. | • Confirmation of accidents record<br>• Record and site inspection<br>• Interview with concerned organizations<br>• Voices and complaints from the local community | Government of Bihar<br>Construction Contractor | PIU | Construction sites and surrounding area | Monthly and when complaints are heard in this regard | Included in construction cost |
| 22-b | | Traffic enforcers will be designated along these areas to assist in directing traffic flow. | | | | | | |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 23 | Cross-border impact and climate change | Planting of shrubbery spices to the limited area under the elevated structures should be considered as necessary to reduce the emission of greenhouse gases. | Same as "1 Air pollution" | | | | | |

Source: JST

## Table 14-62: Environmental Monitoring Plan (Operation Phase)

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 1 | Air pollution | Periodical maintenance of relevant facilities such as ventilation system, substation, and the depot. | Sampling survey using the same methods as the baseline survey for $SO_2$, $NO_2$, $PM_{10}$, $PM_{2.5}$, CO, Ozone and any other necessary items | PMRCL | Government of Bihar | Measured points during the baseline surveys | Twice a year for the first three year (Once in the dry season and once in the rainy season) | Included in the operational cost of PMRCL 12,000/point |
| 2 | Water pollution | Periodical maintenance of relevant facilities such as toilet installed at every station and the depot. | Sampling survey using the same methods as the baseline survey.<br>[Surface water]<br>BOD, COD, DO, Colour, Odour, Taste, pH, Turbidity, Temperature<br>[Groundwater]<br>Colour, Odour, Taste, pH, Turbidity, Temperature, Total Hardness as $CaCO_3$, Total Dissolved Solids, Nitrates ($NO_3$), Fluorides (F), Iron (Fe), Coliform, E-Coli | PMRCL | Government of Bihar | Measured points during the baseline surveys | Twice a year for the first three year (Once in the dry season and once in the rainy season) | Included in the operational cost of PMRCL<br>Ground water: 10,000/point<br>Surface water: 10,000/point |
| 3 | Waste | Installation of enough garbage bin at appropriate location in stations and the depot and collection rules based on local collection systems. | • Confirmation of waste disposal forms<br>• Confirmation of voices and complaints Waste management condition<br>• Voices and complaints from the local community and passenger | PMRCL | Government of Bihar | Every station and Depot sites | Twice a year for the first three year | Included in the operational cost of PMRCL |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 4-a | Soil contamination | Necessary facilities and equipment for preventing leaking oil shall be prepared at the depot. | Sampling survey using the same methods as the baseline survey pH, Electrical Conductivity, Lead (Pb), Mercury (Hg), Cadmium (Cd), Arsenic (As), Cyanide (Cn) and Chromium (Cr+6) | PMRCL | Government of Bihar | Measured points during the baseline surveys | Twice a year for the first three year (Once in the dry season and once in the rainy season) | Included in the operational cost of PMRCL 10,000/point |
| 4-b | | Regular preventive maintenance service of transformer should be strictly implemented | Maintenance record of transformer | | | Receiving substations | Twice a year for the first three year | Included in the operational cost of PMRCL |
| 5-a | Noise and vibration | Additional installation of noise shield at the elevated section. | • Noise and vibration level (LAeq, Lvmax)<br>• Voices and complaints from the local community | PMRCL | Government of Bihar | Points exceeding the standard and where complaints are raised | Whenever complaints are heard in this regard | Included in the operational cost of PMRCL<br>Noise and vibration: 70,000/point |
| 5-b | | At the station platform, paging and train melody volume shall be adjusted to the lowest level where it will not detract from their function. | Same methods as the baseline survey<br>On weekday<br>[Noise] LAeq<br>[Vibration] Lvmax | | | the baseline surveys | Twice a year for the first three year | |
| 5-c | | Slow speed in curve sections | • Railway operation plan<br>• Voices and complaints from the local community | | | Curve points | Whenever complaints are heard in this regard | |
| 6 | Ground subsidence | No specific measures but necessary monitoring for "just in case". Measures taking for the case are to be discussed to determine the best solution suitable for the conditions. | Measurement of control points Ground subsidence level | PMRCL | Government of Bihar | The construction sites | Twice a year for the first three year | Included in the operational cost of PMRCL |
| 7-a | Offensive odor | Regular cleaning and collection of the general waste from stations and depot. | • Record and Site observation<br>• Confirmation of voices and | PMRCL | Government of Bihar | Every station, Depot sites | Twice a year for the first | Included in the |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 7-b | | Installation of appropriate garbage bin with cover. | complaints Odor<br>• Voices and complaints from the passenger and the local community | | | and the surrounding area | three year | operational cost of PMRCL |
| 8 | Ecosystem | Reduction of light pollution during night hours by keeping lights directed and shielded. | Visual observation of implementation status | PMRCL | Government of Bihar | Every station, Depot sites and the surrounding area | Twice a year for the first three year | Included in the operational cost of PMRCL |
| 9 | Local economy such as employment and livelihood, etc. | Monitoring impact on drivers of bus, three wheeler, and other alternative transportation around the Metro. Livelihood assistance or job meditation including the Metro related opportunities. | • Consultation meeting and/ or other means of communication with the bus service and the drivers<br>• Confirmation of voices and complaints State of provision of social assistance<br>• Level of income and livelihood change of drivers<br>• Voices and complaints from the drivers | PMRCL | Government of Bihar | Along the Metro and the surrounding areas | Twice a year for the first three year | Included in the operational cost of PMRCL |
| 10 | Land use and utilization of local resources | Coordination with local government and private developers for healthy socio-economic development along the Metro lines. | • Confirmation plans of the projects and the development plan Status of other projects<br>• Development plan by local government | Government of Bihar<br>PMRCL | Government of Bihar | Along the Metro and the surrounding areas | Twice a year for the first three year | Included in the operational cost of PMRCL |
| 11-a | Gender | Active employment of female staff for PMRCL with fair conditions | • Confirmation of employment record<br>• Confirmation of voices and complaints from female staff of PMRCL | PMRCL | Government of Bihar | HQ of PMRCL | Twice a year for the first three year | Included the company budget |
| 11-b | | Keep provision of the designated seat for female in the train, enough number of toilet and other facilities as much as possible. | • Site observation<br>• Confirmation of voices and complaints from female passengers<br>• Status of introduction of the designated seat for female | | | Every station | | |
| 12-a | Health (Infectious diseases such as HIV/AIDS, etc.) | A periodic awareness program for the PMRCL officials | • Confirmation of health checklist of the officials<br>• Interview with concerned organizations | PMRCL | Government of Bihar | Every station, Depot sites, trains and HQ | Twice a year for the first three year and when | Included the company budget |
| 12-b | | A periodic health check-up program for the PMRCL officials | | | | | | |

| No. | Impact Item | Mitigation Measure | Method / Survey Item | Implementation Body | Responsible Body | Location | Frequency | Cost (INR) |
|---|---|---|---|---|---|---|---|---|
| 12-c | | [Countermeasures for COVID-19]<br>• Air circulation in the train by air conditioning<br>• Cleaning rolling stocks periodically<br>• Opening the windows in the train<br>• Promotion of staggered working hours<br>Installation of disinfectants at every toilet and ticket gate | • Confirmation of voices and complaints Number of infected cases<br>• Voices and complaints from the officials and the passengers | | | | complaints are heard in this regard | |
| 13 | Cross- border impact and climate change | Periodical maintenance of relevant facilities such as ventilation system, substation, and the depot. | Same as “1 Air pollution” | | | | | |

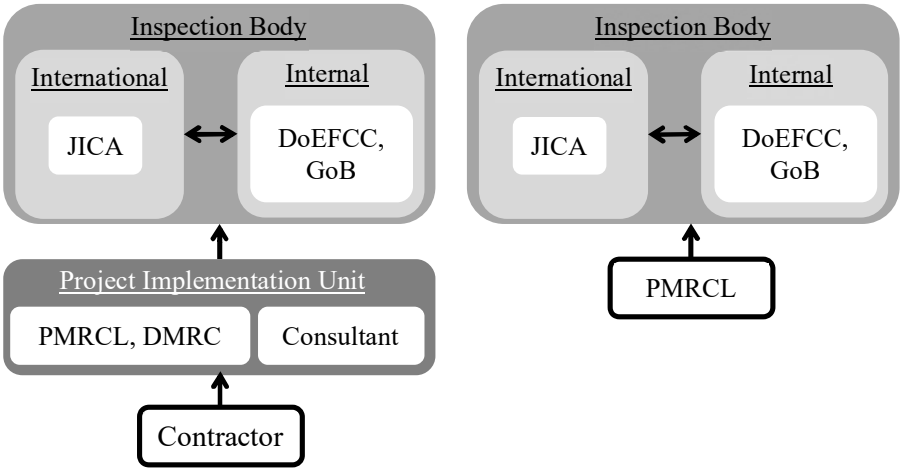
Source: JST

## 14.10 Project Implementation System

### 14.10.1 Mitigation Measures and Monitoring Plan

This section describes the implementation system of the proposed mitigation measures and monitoring plan. At the Pre-construction/ Construction phase, the contractor will make periodic reports to the Project Implementation Unit (PIU), then the PIU will submit the periodic reports to JICA regarding the progress. The reporting frequency to JICA will be quarterly. If necessary, the PIU will report at any time to the Department of Environment, Forest and Climate Change (DoEFCC), Government of Bihar (GoB), the environmental supervising agency in Patna, to ask for their instructions. Also, at the operation phase, PMRCL, as the responsible agency, will make periodic reports to JICA. The reporting frequency to JICA will be biannually for 2 years after the operation commencement. Same as the Pre-construction/ Construction phase, PMRCL will report at any time to DoEFCC to ask for their instructions, if necessary.

Regarding the staff organization of PMRCL, since PMRCL does not employ any special staff for EIA and SIA currently, some engineers from other sectors also have responsibility for EIA and SIA. Therefore, PMRCL shall actively hire some staff according to the scale and progress of the project. As an example of DMRC, there was a few staff for EIA and SIA when inaugurated, but currently there are dozens of staff in the sector by hiring staff little by little every year.

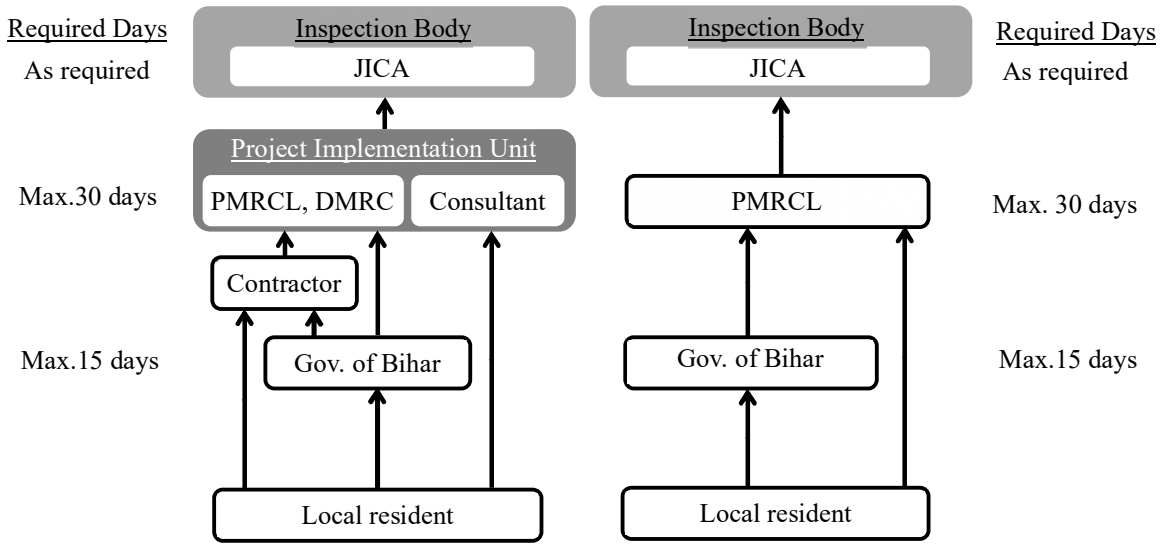



Source: JST

**Figure 14-39: Draft Implementation System at Each Phase**

### 14.10.2 Grievance Redress Mechanism

Grievances of residents and stakeholders should be responded to by the State Government of Bihar (GoB), which are the responsible municipalities, or by the PIU. Since public hearings were held organized by GoB, and GoB might have their strong connections with the residents, it is also easier for the residents to consult with GoB about their complaints. As shown in the figure below, residents should file their complaints directly with the PIU or indirectly with PIU through Contractor and GoB at the construction phase, with PMRCL at the operations phase, or with GoB as the liaison municipalities to continue discussions. A 45-day period is assumed as the maximum period of grievance redress at the construction phase and operations phase.




Source: JST

**Figure 14-40: Draft Grievance Redress Mechanism at Each Phase**

# 15. Social Impact Assessment (SIA)

## 15.1 Baselines of Social Environment

### 15.1.1 GDP and Industry

As shown in the following table, the GDP per capita of Bihar shows an annual growth of about 2% to 5%, with base year 2011-12. A high growth of about 9% was achieved in the 2018-2019 fiscal year. According to the 2020 EIA report, Patna's economic growth rate was 21st in the world and 5th highest in India as of 2015. However, compared to the GDP of states and regions in India, the ranking continues to be the lowest. The highest per capita GDP for the 2020-21 fiscal year is 307,108 INR in Goa, which is about 10 times higher than in Bihar (31,017 INR). In the 2020-21 fiscal year, Uttarapradesh had the second lowest GDP per capita after Bihar, with an amount of 42,887 INR (1.38 times that of Bihar).

**Table 15-1: Per Capita Net State Domestic Product at Constant Prices; Base Year 2011-12**

| Item | Unit | 11-12 | 12-13 | 13-14 | 14-15 | 15-16 | 16-17 | 17-18 | 18-19 | 19-20 | 20-21 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Bihar | INR | 21,750 | 22,201 | 22,776 | 23,223 | 24,064 | 25,455 | 26,719 | 29,092 | 30,621 | 31,017 |
| Rank among 33 States (32 in 20-21) | Rank | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 33 | 32 |
| Growth from previous year | % | - | 2.08 | 2.59 | 1.96 | 3.62 | 5.78 | 4.97 | 8.88 | 5.26 | 1.29 |

Source: PER CAPITA NET STATE DOMESTIC PRODUCT AT CONSTANT PRICES; BASE YEAR 2011-12, https://www.mospi.gov.in/c/document_library

According to the Bihar Economic Survey 2019-20, the Finance Department of Bihar, the economic situation in the state is as follows:

Bihar has consistently achieved socio-economic development over the last decade, despite the limited financial resources available. Gross domestic product (GSDP) growth in 2018-19 was 10.53% (adjusted price) and 15.01% (current price), which is higher than that of India. The percentages of primary, secondary and tertiary industries in Gross Value Added (GSVA) are 21.3%, 19.7% and 59.0%, respectively. Within the secondary industry, construction and manufacturing are GSVA's major contributors, with shares of 9.5% and 8.2% in 2018-19, respectively, with these shares remaining nearly flat for the past five years. The contribution of the secondary industry as a whole has remained between 19 and 20% between 2013-14 and 2018-19. In the tertiary industry, trade / repair services (18.2%) and real estate / home ownership / professional services (9.1%) contribute significantly to GSVA. The share of the total tertiary industry in GSVA increased between 2012-13 and 2018-19. As evidenced by various indicators, there are considerable disparities between districts in the state in terms of socio-economic development. Based on gasoline consumption per thousand people, the three relatively affluent districts are Patna, Muzafarpur and Goparganji. The three richest districts in terms of small per capita savings are Patna, Saran and Buksar.

Agriculture supports more than three-quarters of the population's livelihood, while the agricultural sector's contribution to the state's GSVA in 2017-18 was about 20%, and in 2018-19, 10.64%. Limited land resources, fragmented land tenure, and irregular rainfall are risk factors. In addition to food grains, vegetables and fruits, livestock (especially dairy cows), fishing, and aquaculture are prosperous. Total fish

production has increased from 479,000 tons in 2013-14 to 602,000 tons in 2018-19.

Bihar's industry has developed its agricultural processing industry based on its comparative advantage in the agricultural sector, with strong dairy and sugar production. In addition, the textile industry, sericulture and silk reeling are also active. In addition, the Bihar Industrial Area Development Corporation (BIADA) is working to promote the industrialization of Bihar through the development of industrial complexes. Meanwhile, official data on informal enterprises show that a significant portion of the working-age population engages in small-scale production activities, making a contribution to state capital formation and job creation. Furthermore, in the mining industry, copper and zinc resources are distributed in addition to the extraction of sand and stone and the brick production.

In the service industry, the number of domestic tourists is increasing year by year due to the large distribution of religious tourism resources such as Buddhism, Jainism, and Sikhism in the state. The number of tourists entering the state in 2018-19 was 336,200,000. Of these, the number of tourists from overseas was 1.09 million. The ranking of Bihar within the 36 states and union territories was 15th in the number of domestic tourists, and 9th in the number of overseas tourists.

### 15.1.2 Population, Language, Castes, Indigenous Peoples and Ethnic Minorities

The latest Population Census of India was conducted in 2011. The Municipality Corporation of Patna, where the Project is located, had a population of approximately 1.68 million (males: 893,399 and females: 790,823), which is 28.8% of the total population of Patna District. The population density is 6,737 persons/km$^2$, which is three to six times higher than that of Patna District and State of Bihar, respectively.

By calculation, average household size of Patna Municipality Corporation is 5.72 person per household, and 5.98 person per household in Patna District. On the other hand, CMP Patna 2018[49] Study found the average household size in the study area as 6.7 persons per household.

**Table 15-2: Population, Population Density and Households**

| Administrative Unit | Population | Area (km$^2$) | Population Density (Person/km$^2$) | Household |
|---|---|---|---|---|
| Patna Municipality Corporation | 1,684,222 | 250 | 6,737 | 294,612 |
| Patna District | 5,838,465 | 3,202 | 1,823 | 975,578 |
| State of Bihar | 104,099,452 | 94,163 | 1,106 | 18,913,565 |
| India | 1,210,854,977 | - | - | 249,501,663 |

Source: 2011 Census of India (population), Government of Bihar (area)

Patna is divided into six administrative Circles, each of which is divided into 8 to 16 Wards. According to the Patna City Population Census 2011-2022, the Patna Metropolitan Area consists of Patna City (Patna) and the surrounding areas of Badalpura, Dinapur Cantonment, Dinapur Nizamat, Khagaul, Nohsa, Pataliputra Housing Colony, Phulwari Sharif, and Saidpura.

[49] Comprehensive Mobility Plan Patna (2018) studied a total of 3,664 household interview samples in 2018. It adds on to the socio-economic data obtained in the RITES Primary surveys in 2013, in which a total of 6,626 households were interviewed in the study area representing the 89 traffic analysis zones covering Patna City area, which is the same area as covered in the DPR. (p.3-1, DPR)

In May 2022, JST interviewed an SIA expert hired by the District Administration to implement the SIA survey under the Land Acquisition Law (2013) on behalf of the State. According to the SIA expert, there are no publicly available administrative boundary maps. Therefore, the expert is conducting the State SIA survey while preparing an approximate boundary map based on information obtained from interviews.

**Table 15-3: Circles and Wards in Patna Municipality Corporation**

| Name of Circle | Number of Wards |
|---|---|
| New Capital Circle | 16 |
| Patliputra Circle | 16 |
| Kankarbagh Circle | 11 |
| Bankipur Circle | 12 |
| Azimabad Circle | 12 |
| Patna City Circle | 8 |

Source: Patna Municipality Corporation
https://pmc.bihar.gov.in/about.aspx

The official language of Bihar is Hindi, with Maithili and Urdu as the other recognized languages. The table below shows the mother tongues of Bihar's population. There are about 50% population who speaks mother language other than the three official or recognized languages.

**Table 15-4: Language in State of Bihar**

| Language | State of Bihar | India |
|---|---|---|
| Hindi | 25.62% | 43.63% (1st place) |
| Maithili | 12.58% | 1.12% (13th place) |
| Urdu | 8.45% | 4.19% (7th place) |
| Bhojpuri | 24.93% | |
| Magahi | 10.90% | |
| Surjapuri | 1.79% | |
| Other Hindi dialects | 14.31% | |
| Other language | 1.42% | |

Source: 2011 Census of India, Government of India National Sample Survey Office

According to the results of the 2011 Census, about 16% of Bihar's population belongs to Scheduled Castes (Dalits and Mahadalits). Of the 23 sub-castes nationwide included in Mahadarit, 21 sub-castes exist in the State. The 21 sub-castes are: Bantar, Bauri, Bhogta, Bhuiya, Chaupal, Dabgar, Dom (Dhangad), Ghasi, Halalkhor, Hari (Mehtar, Bhangi), Kanjar, Kurariar, Lalbegi, Musahar, Nat, Pan ( Swasi), Rajwar, Turi, Dhobi, Chamar, Dusadh.

In Bihar, there are about 130 castes classified as Extremely Backward Castes (EBCs).

For indigenous peoples and ethnic minorities, about 1.3% of the state's population belongs to the Scheduled Tribes, including people from communities such as Gondi, Santhal, and Tharu. As explained in Section 15.13, no indigenous or ethnic minority communities were found in the area along the 2 corridors of the Project.

**Table 15-5: Religion and Caste in State of Bihar**

| Group | Ratio | Included Castes and groups |
|---|---|---|
| Hindus | 82.7% | |
| Scheduled Castes (SC) (Dalit + Mahadalit) | 16% | Dusadh 5%, Chamar 5%, Musahar 2.8% |
| Other backward castes (OBC), Extremely backward castes (EBC) | 48-50% | |
| Forward Caste | 18% | Brahmin 6%, Bhumihar 7.2%, Rajput 7.2%, Kayasthas 1% |
| Muslims | 16.9% | Sayyid, Sheikh, Mugal, Pathan |
| Scheduled Tribes | 1.3% | |
| Other | 0.4% | Christians, Sikhs, Jains, Buddhists |

Source: 2011 Census of India, Government of India National Sample Survey Office

### 15.1.3 Literacy and Education

The literacy rate in Bihar, where this project is located, is 60%, 72% in urban and 59% in rural. Large differences of literacy rate is found by gender and region, with literacy rate of 67% of men (urban: 78%, rural (66%) and 52% of women (urban: 66%, rural 50%). In addition, according to the results of a 2014 sample survey on final education level in India, the proportion of the population below Primary is high in Bihar, and the proportion of people who have been educated above Upper primary is low, compared to the figures for the whole of India.

**Table 15-6: Final Education Level in Bihar and India**

| Area | Illiterate | Literate with no education | Less than Primary | Primary | Upper primary | Secondary | Higher secondary | Diploma/ Certificate | Graduate | Post graduate & above |
|---|---|---|---|---|---|---|---|---|---|---|
| Bihar | 32.5 | 1.1 | 20.9 | 14.0 | 11.9 | 9.9 | 5.3 | 0.7 | 3.3 | 0.3 |
| India | 24.3 | 0.9 | 17.2 | 14.8 | 15.0 | 11.4 | 7.6 | 1.5 | 5.7 | 1.6 |

Source: Education in India (January - June, 2014) government of India National Sample Survey Office

The distribution of population by educational levels in the 'RITES Primary surveys[50] ' in 2013 is presented in following table. The members of household with age below four years have been considered as children. About 41.8% have education below 10th, 22.5% have education level between 10th-12th level. Only 6.5% of the surveyed samples are illiterate.

**Table 15-7: Distribution of Household Members by Education Level**

| SN | Education | No. of Sampled Household Members | Percentage (%) |
|---|---|---|---|
| 1 | Illiterate | 2,030 | 6.5 |
| 2 | Below $10^{th}$ | 13,015 | 41.8 |
| 3 | $10^{th}$ to $12^{th}$ | 6,987 | 22.5 |
| 4 | Graduate | 5,319 | 17.1 |
| 5 | Post Graduate | 1,217 | 3.9 |
| 6 | Professional | 435 | 1.4 |
| 7 | Child | 2,101 | 6.8 |
| **Total** | | **31,104** | **100.0** |

Source: RITES Primary Survey

[50] During RITES Primary surveys in 2013, a total of 6,626 households were interviewed in the study area representing the 89 traffic analysis zones covering Patna City area, which is the same area as covered in the DPR. (p.3-24, DPR)

### 15.1.4 Number of Earning Members per Household

The distribution of earning members per household in the study area is presented in the following table.

It is seen that 61% of the households have only 1 earning member, 29% have 2 earning members, 8% have 3 earning members and about 22 % have more than 3 earning members.

**Table 15-8: Distribution of Households by Number of Earning Members**

| SN | No. Workers | No. of Sample Household | Percentage |
|---|---|---|---|
| 1 | 1 | 4,023 | 60.7 |
| 2 | 2 | 1,963 | 29.6 |
| 3 | 3 | 512 | 7.7 |
| 4 | 4 | 83 | 1.3 |
| 5 | 5 | 29 | 0.4 |
| 6 | 6+ | 16 | 0.2 |
| **Total** | | **6,626** | **100** |

Source: RITES Primary Survey

### 15.1.5 Activity Status/ Occupation

The occupational structure of the surveyed household members is presented in the following table.

About 68.8% samples are non-workers comprising of students, housewives, retired and unemployed people.

31.2% samples are engaged in occupation; of which equal percentage i.e. 15% are engaged in business and service sector. Among the service class, majorly about 10% are engaged in private sector, where about 6% are engaged in government services.

**Table 15-9: Distribution of Household Members by Occupation**

| SN | Occupation | No. of Sampled Household Members | Percentage |
|---|---|---|---|
| 1 | Govt. Service | 2,024 | 6.5 |
| 2 | Pvt. Service | 2,994 | 9.6 |
| 3 | Business | 4,688 | 15.1 |
| 4 | Student | 10,178 | 32.7 |
| 5 | House Wife | 7,493 | 24.1 |
| 6 | Retired | 593 | 1.9 |
| 7 | Unemployed | 812 | 2.6 |
| 8 | Others | 2,322 | 7.5 |
| | **Total** | **31,104** | **100** |

Source: RITES Primary Survey

### 15.1.6 Female Labour Force Participation

According to the Periodic Labour Force Survey (July 2017-June 2018)(National Statistics Office India), Bihar registered the lowest female labour force participation rate (LFPR) among all State and Union Territories of India at merely 4% in rural areas and 6.5% in urban areas. According to SEWA Bharat (All India Federation of Self- Employed Women's Association), an NGO working in the field, One of the reasons for such a low level of Female Work Participation Rate in Bihar has been the traditional social norm of

limiting female role within household, and not encouraging female population to go out of house to take part in the labour force.

The distribution of workers by status of employment suggests that 40% of female workers in Bihar were self-employed, either as own account workers (32.3%) or as helpers in household enterprises (7.7%). The primary sector continues to provide bulk of the employment opportunities. The agriculture, forestry and fishing sector absorbed 66.8% of female workers. SEWA Bihar primarily assists home-based artisans, handloom weavers, domestic workers, farmers and agricultural producers, construction workers, vendors, and domestic workers.

On the other hand, since 2013, 35 %of the 47,000 vacant posts of Bihar Police in the rank of constables and sub-inspectors will be reserved for women. As a result, female personnel in the Bihar police reached more than 25% in 2021. Bihar also reserves 50 % of teaching jobs and the panchayats jobs for women.

From 2016, the Bihar State also has 35 % reservation for women in government jobs and engineering, medical, and technical education colleges. A similar quote will be reserved for women in an upcoming sports university in the state.

This reservation also extends to promotions. Resultantly, the government department heads have been asked to make sure that 35 per cent of boards at every level should benefit women officials. This policy would ensure an increased number of female staff in higher positions in block development officers (BDO), circle officers (CO), station house officers (SHO), and sub divisional magistrates (SDM).[51]

### 15.1.7 Income Distribution

The average monthly household income in the study area is INR.23,640.

The distribution of sample household by monthly income indicates that 33% of the population earning Rs 5,000 to Rs. 10000 followed by 25%, earning between Rs. 10,001 to Rs. 15,000 and 15% between Rs. 15,001 to Rs. 25,000.

A considerable percentage of 19% population is earning even less than or equal to Rs. 5000 per month.

Only, about 8% of the population is having their monthly income more than 25000.

**Table 15-10: Distribution of Households by Monthly Household Income**

| SN | Income Group | No. of Sample Household | Percentage (%) |
|---|---|---|---|
| 1 | < INR. 5,000 | 6,047 | 19.4 |
| 2 | INR 5,001 – INR10,000 | 10,289 | 33.1 |
| 3 | INR 10,001 – INR15,000 | 7,661 | 24.6 |
| 4 | INR 15,001 – INR25,000 | 4,774 | 15.3 |
| 5 | INR 25,001 – INR50,000 | 2,274 | 7.3 |
| 6 | INR50,000< | 59 | 0.2 |
| | Total | 31,104 | 100.0 |

Source: RITES Primary Survey

[51] https://thelogicalindian.com/good-governance/bihar-government-reserves-35-for-women-officers-29045

### 15.1.8 Poverty Line and Multidimensional Poverty Index (MPI)

#### (1) Poverty Line

In 2014, the Rangarajan Commission calculated that the poverty line in India as 972 INR / person / month in rural areas and 1,407 INR / person / month in urban areas (adjusted price based on 2011-12). The poverty lines of India as a whole and Bihar calculated in 2011 are as shown in the following table. The poverty lines of Bihar are about 10% lower (poorer) than those of India. In addition, 33.74% of Bihar's population falls under the poverty line, compared to national average of 21.92%.

**Table 15-11: Poverty Line of India and Bihar per Person per Month**

| | Rural (2011-12) (INR/person/month) | Urban (2011-12) (INR/person/month) | Population Ratio below Poverty Line (%) |
|---|---|---|---|
| India | 816 | 1,000 | 21.92 |
| Bihar | 778 | 923 | 33.74 |

Source: "Handbook of Statistics on Indian Economy. Table 154: Number and Percentage of Population below Poverty Line. (2011-12)" (https://www.rbi.org.in/scripts/PublicationsView.aspx?id=19887) Reserve Bank of India. Retrieved 2021-09-13

Using the Urban poverty line of INR. 923 /person/month in Bihar with various average household size shown in the table below, monthly income for a household poverty line can be calculated between INR. 4,500 and INR. 6,200 per household per month, or annual income between INR. 54,000 and INR. 74,400 per household per year.

**Table 15-12: Calculated Poverty Line per Household per Month**

| Household Size Source | Household Size (person/household) | Urban Poverty Line in Bihar (INR/person/month) | Calculated Poverty Line: Monthly Household Income (INR/household) | |
|---|---|---|---|---|
| | | | Monthly income | Yearly income |
| DPR SIA 2020 p.41 | 4.9 | 923 | 4,523 | 54,276 |
| Population Census of India 2011, Patna Municipality Corporation | 5.72 | 923 | 5,280 | 63,360 |
| CMP Patna 2018 Study | 6.7 | 923 | 6,184 | 74,208 |

Poverty line of monthly household income was calculated by equations:
Monthly = Household size x Urban poverty line (monthly)
Yearly = Household size x Urban poverty line (monthly) x 12
Source: JST

#### (2) Multidimensional Poverty Index

The Multidimensional Poverty Index (MPI) was introduced by the United Nations Development Program in the 2010 Human Development Report to clarify the extent and frequency of poverty in terms of health, education and living standards. The MPI is composed of indicators that focus on clarifying the degree and frequency of poverty in developing countries, but it is a leading effort to grasp poverty from multiple perspectives. For each household, it is judged whether or not each item constitutes multidimensional poverty, and if applicable, points weighted according to the item are added. When the total score is above the standard value, it is defined as a "poor household". Ultimately, the MPI index of each country will be calculated by using the number of households defined as being in poverty and the score for each household, and it will be a single index that can be compared between nations.

**Table 15-13: Contribution of Indicators to MPI Score**

| Field | | Index | Weight |
|---|---|---|---|
| Education | 1. Years of Schooling | No household members have more than 6 years of school experience | 1/3×1/2＝0.167 |
| | 2. School Attendance | Children of schooling age are not in school | 1/3×1/2＝0.167 |
| Health | 3. Child-Adolescent Mortality | Households whose children have died in the last five years up to the date of the survey | 1/3×1/2＝0.167 |
| | 4. Nutrition | There are undernourished adults or children (BMI <18.5 is undernourished for children over 15 years old; children under 15 years old are undernourished with weight <WHO standard z value (median-standard deviation x 2) insufficient.) | 1/3×1/2＝0.167 |
| Standard of Living | 5. Electricity | Not receiving electricity | 1/3×1/6＝0.056 |
| | 6. Sanitation | No improved sewage system or shared improved sewage system with other households | 1/3×1/6＝0.056 |
| | 7. Drinking Water | No safe water available, or it takes more than 30 minutes round trip to get safe water | 1/3×1/6＝0.056 |
| | 8. Housing | The floor of the house is mud, sand or dung | 1/3×1/6＝0.056 |
| | 9. Cooking Fuel | Cook with dung, wood or charcoal | 1/3×1/6＝0.056 |
| | 10. Assets | Not having a radio, TV, phone, bicycle, motorcycle, refrigerator, car, truck | 1/3×1/6＝0.056 |

1. The classifications and indicators that make up the MPI are based on the Human Development Index (HDI)
2. Determine the criteria for each item based on the internationally agreed Millennium Development Goals (MDG) criteria.
3. Give the same weight to each of the three fields of health, education, and standard of living so that the perfect score is 1. All items in each field are also weighted evenly.
4. For each item, 1 point will be given if applicable, and 0 point will be given if not applicable. Weights are applied, and households with a total score of 1/3 or more of all items are identified as poor households. At this time, the total score of households with a total score of less than 1/3 (non-poor households) shall be 0 points.
5. Using the number of households defined as poor households and the score by household in the above procedure, determine the poverty rate and poverty intensity, and calculate the MPI index of each country by the product.
   a. Poverty rate (H) = sum of the number of household members defined as poverty ÷ sum of the number of household members of all surveyed households
   b. Poverty intensity (A) = Σ (total score of each household x number of members of each household) ÷ sum of the number of members of the household defined as poverty
   c. The classifications and indicators that make up MPI = H x A.

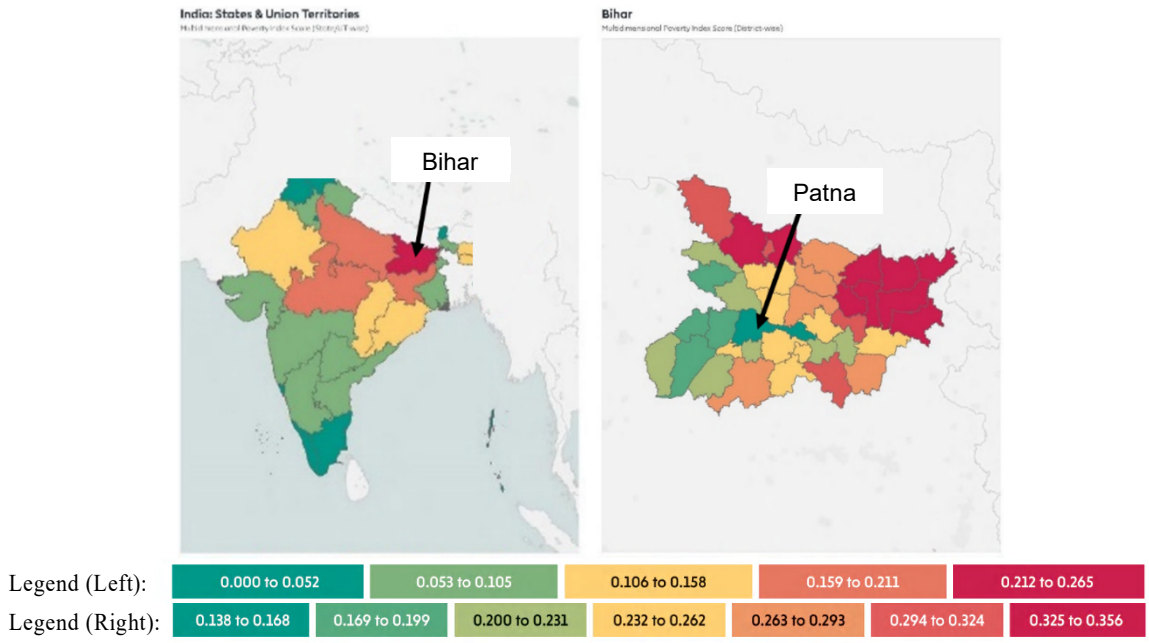
Source: Japan National Cabinet Office "FY 2016 Survey and Research Report for the Development of New Indicators for Child Poverty"
https://www8.cao.go.jp/kodomonohinkon/chousa/h28_kaihatsu/2_02_2_2.html

The status of the Multidimensional Poverty Index (MPI) in Bihar and Patna in the 2015-16 fiscal year in the "India National Multidimensional Poverty Index Baseline Report" published in 2021 is as follows. As shown in Table 15-14, the poverty rate of Patna City as a whole is 29.20% and the MPI is 0.138. On the other hand, the poverty rate of whole India is 25.01% and the MPI is 0.118, both indexes slightly in better condition compared to those of Patna City. The poverty rate in the urban Patna where the Patna Metro line is located is 13.8%, and the MPI is 0.064, which is close to the MPI of 0.04 in urban areas in India.

**Table 15-14: Poverty Rate, Intensity, and MPI in Patna and India**

| | Poverty Rate | Poverty Intensity | MPI | | Poverty Rate | Poverty Intensity | MPI |
|---|---|---|---|---|---|---|---|
| Patna | 29.20% | 47.26% | 0.138 | India | 25.01% | 47.13% | 0.118 |
| Urban | 13.80% | 46.20% | 0.064 | Urban | 8.81% | 45.25% | 0.04 |
| Rural | 45.46% | 47.66% | 0.217 | Rural | 32.75% | 47.38% | 0.115 |

Source: India National Multidimensional Poverty Index Baseline Report, NITI Aayog, 2021, Based on the National Family Health Survey-4 (2015-16)
https://www.niti.gov.in/sites/default/files/2021-11/National_MPI_India-11242021.pdf




Source: India National Multidimensional Poverty Index Baseline Report, NITI Aayog, 2021, Based on the National Family Health Survey-4 (2015-16)
https://www.niti.gov.in/sites/default/files/2021-11/National_MPI_India-11242021.pdf

**Figure 15-1: MPI in Bihar and Patna**

The poverty rates for each index in Patna Municipality Corporation and Bihar are shown in the table below. Bihar has the highest poverty rate out of the 28 Indian States in most items, except for the "safe drinking water" indicator[52]. On the other hand, Patna Municipality Corporation has a lower poverty rate than the whole State of Bihar and is close to the national average. There is, however, still a large gap from the national average in terms of health and nutrition of pregnant women.

[52] India is consisted of 28 States and 8 union territories. The comparison here is made among the 28 states.

**Table 15-15: Poverty Rate of Patna, Bihar and India by Indicator**

| Indicator | | Patna (2015-16) | Bihar (2015-16, otherwise noted) | Ranking among 28 States (In descending order of poverty rate) | India |
|---|---|---|---|---|---|
| Education | 1. Years of Schooling | 14.62% | 26.27% | 1 | 13.88% |
| | 2. School Attendance | 7.04% | 12.52% (2015-16)<br>9.80% (2019-20) | 1 | 6.40% |
| Health | 3. Child-Adolescent Mortality | 3.28% | 4.58% | 2 | 2.69% |
| | 4. Nutrition | 42.86% | 51.8% | 1 | 37.60% |
| | 5. Maternal Health | 37.56% | 45.62% | 1 | 22.59% |
| Standard of Living | 6. Electricity | 13.05% | 39.86% (2015-16)<br>3.70% (2019-20) | 1 | 12.16% |
| | 7. Sanitation | 48.61% | 73.61% (2015-16)<br>50.60% (2019-20) | 2 | 51.97% |
| | 8. Drinking Water | 1.97% | 2.34% (2015-16)<br>1.70% (2019-20) | 27 | 14.60% |
| | 9. Housing | 38.07% | 73.73%(2015-16)<br>65.30% (2019-20) | 5 | 45.65% |
| | 10. Cooking Fuel | 50.40% | 82.92% (2015-16)<br>63.20% (2019-20) | 1 | 58.48% |
| | 11. Assets | 16.51% | 24.32% | 3 | 13.97% |
| | 12. Bank Account | 10.83% | 26.00% (2015-16)<br>4.00% (2019-20) | 2 | 9.66% |
| MPI | | 0.138 | 0.265 | | 0.118 |

Note: Poverty Rate is that of Uncensored Headcount.

Source: India National Multidimensional Poverty Index Baseline Report, NITI Aayog, 2021, Based on the National Family Health Survey-4 (2015-16)
https://www.niti.gov.in/sites/default/files/2021-11/National_MPI_India-11242021.pdf

### 15.1.9 Sanitation and Health

Infant mortality rates in Bihar and India, shown in the following table, are almost the same as the world average.

**Table 15-16: Infant mortality rates in Bihar and India**

| Area | Infant Mortality Rates (deaths per 1,000 live births) |
|---|---|
| State of Bihar (2019) | 29 |
| India Average (2019) | 30 |
| World Average (2018) | 29 |

Source: Status of IMR and MMR in India, The State of the World's Children 2018, UNICEF

On the other hand, the 0-5 year old population ratio in Bihar (10.7%) is higher than the national average (8.6%), and the 61 year old and over population ratio (3.4%) is lower than the national average (6.6%). Looking at life expectancy, there is no difference between Bihar (68.9 years) and the whole country (69 years) in the whole population. But looked at by gender, in Bihar, the average life expectancy of men (69.2 years) is the national average. It is longer than (67.8 years) and the average life expectancy of women (68.6

years) is shorter than the national average (70.4 years). Inpatients and chronic illnesses have both been lower than the national average (3.7% and 3.1%, respectively) in Bihar (2.8% and 0.5%, respectively) over the past year.

Looking at the average life expectancy, in the whole population, there is no difference found between Bihar (68.9 years old) and India (69 years old). By gender, the average life expectancy of men in Bihar (69.2 years) is longer than the national average (67.8 years). The average life expectancy of women in Bihar (68.6 years) is shorter than the national average (70.4 years).

The inpatient rate for the past 1 year is 2.8% in Bihar, which is lower than the national average of 3.7%. The proportion of chronically ill patients over the past 1 year is 0.5% in Bihar, which is lower than the national average of 3.1%.

**Table 15-17: Life Expectancy and Patient Rates in Bihar**

| Area | 0-5 Year Old Population Ratio (%) | 61 Year Old and Over Population Ratio (%) | Life Expectancy (Years) | Male Life Expectancy (Years) | Female Life Expectancy (Years) | Inpatient Rate for the past 365 days (%) | Chronically Ill Patients (%) |
|---|---|---|---|---|---|---|---|
| Bihar | 10.7 | 3.4 | 68.9 | 69.2 | 68.6 | 2.8 | 0.5 |
| India | 8.6 | 6.6 | 69 | 67.8 | 70.4 | 3.7 | 3.1 |

Source: Health in India (July 2017 - June 2018), Government of India National Statistical Office
Average Life Expectancy (SRS Based Life Table 2013-17), Office of the Registrar General & Census Commissioner, Government of India

### 15.1.10 Vehicles Owned per Household

Distribution of households owning vehicles is presented in following table.

Majorly households have an ownership of two wheelers and cycles i.e. 44% and 47% respectively.

Only, 7% of the households have an ownership of car in the study area.

**Table 15-18: Distribution of Households by Vehicle Ownership**

| | OWNERSHIP | | | | Total |
|---|---|---|---|---|---|
| | Car | Two-Wheelers | Cycle | Others | |
| **No. of Households** | 507 | 2,893 | 3,098 | 128 | **6,626** |
| **Percentage%** | 7.7 | 43.7 | 46.8 | 1.9 | **100** |

Source: RITES Primary Survey

### 15.1.11 Household Monthly Expenditure on Transport

The distribution of the individuals of sampled household according to monthly expenditure on Transport is shown in next Table.

About 86.7% of Households spend less than or equal to INR. 500 per month on Transport, while only 10.3% & 2.9 have monthly expenditure on transport ranging between INR. 501 – 1,000 and INR.1,001 – 3,000 respectively.

**Table 15-19: Distribution of Individuals by Average Monthly Expenditure on Transport**

| S. No. | Expenditure on Transport | No. of Sample Household | Percentage (%) |
|---|---|---|---|
| 1 | Nil | 15,339 | 49.3 |
| 2 | <= INR.100 | 1,899 | 6.1 |
| 3 | INR. 101- INR.200 | 3,606 | 11.6 |
| 4 | INR.201- INR.300 | 3,164 | 10.2 |
| 5 | INR. 301- INR.500 | 2,952 | 9.5 |
| 6 | INR.501- INR.750 | 1,612 | 5.2 |
| 7 | INR.751- INR.1000 | 1,579 | 5.1 |
| 8 | INR.1001- INR.1500 | 534 | 1.7 |
| 9 | INR. 1501- INR.3000 | 365 | 1.2 |
| 10 | > INR.3000 | 54 | 0.2 |
| **Total** | | **31,104** | **100** |

Source: RITES Primary Survey

### 15.1.12 Trip Purpose

The distribution of daily vehicular and walk trips is presented in the next table.

It is observed that about 51.1% and 23.7% of daily vehicular and walk trips have been performed for work purpose respectively. For education purpose, 63.8% of trips have been performed by walk trips.

**Table 15-20: Distribution of Vehicular and Walk Trips by Purpose**

| | Vehicular Trips | | Walk Trips | | |
|---|---|---|---|---|---|
| | No. of Trips | Share (%) | No. of Trips | Share (%) | Total |
| **Work** | 15,582 | 51.1 | 3,320 | 23.7 | 18,902 |
| **Education** | 10,597 | 34.8 | 8,914 | 63.8 | 19,511 |
| **Others** | 4,312 | 14.1 | 1,747 | 12.5 | 6,059 |
| **Total** | **30,491** | **100** | **13,981** | **100** | **44,472** |

Source: RITES Primary Survey

### 15.1.13 Traffic and Transportation in Patna

#### (1) Vehicular Growth and Composition

Total vehicles in Patna city have largely increased between the years 2011 and 2018. The share of two-wheelers registration comprises about 75%, while cars comprise about 13 %.

**Table 15-21: Vehicles Registration in Patna**

| | Year | | | | | | |
|---|---|---|---|---|---|---|---|
| | **2011-12** | **2012-13** | **2013-14** | **2014-15** | **2015-16** | **2016-17** | **2017-18** |
| Trucks | 2,882 | 3,251 | 3,167 | 2,868 | 383 | 3,872 | 2,866 |
| Bus | 302 | 352 | 244 | 308 | 601 | 595 | 435 |
| Car | 12,493 | 13,805 | 12,537 | 11,033 | 13,643 | 18,113 | 14,863 |
| Taxi | 1,181 | 1,574 | 1,488 | 1,242 | 776 | 1,358 | 1,197 |
| Jeep | 2,515 | 1,706 | 1,740 | 1,800 | 1,538 | 1,967 | 3,096 |
| Three-Wheeler | 3,801 | 4,432 | 6,205 | 6,087 | 4,171 | 6,429 | 3,543 |
| Two-Wheeler | 50,917 | 57,836 | 58,134 | 66,889 | 74,335 | 84,008 | 84,202 |
| Tractor | 1,383 | 1,410 | 1,649 | 2,033 | 2,028 | 3,355 | 1,302 |
| Trailer | 839 | 846 | 693 | 516 | 806 | 2,134 | 784 |
| Other | 30 | 21 | 5 | 2 | 18 | 14 | 3 |
| **Total** | **76,343** | **85,233** | **85,862** | **92,778** | **98,299** | **121,845** | **112,291** |

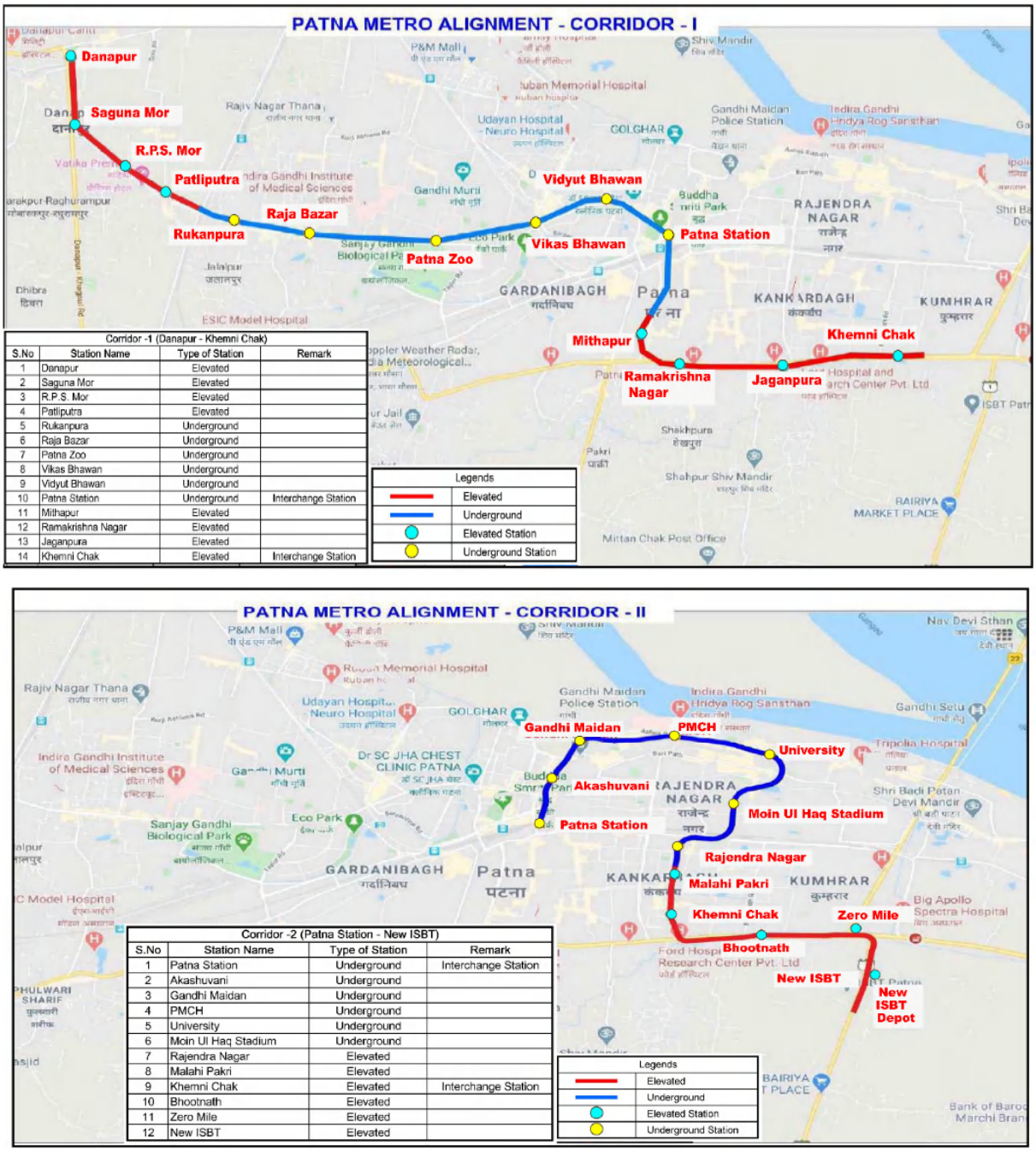
Source: CMP Patna (2018)

### (2) Major Transport Nodes

Terminals are the major transport nodes that attract and produce high number of trips every day. At present, there are two bus terminals in the city. One of them is at Mithapur (Pvt. Bus Terminal), which is the major terminal for intercity buses and the second is at Gandhi Maidan which also caters to the intercity buses. As per CMP Patna 2018, Mithapur Bus Terminal caters to the 73,239 passengers daily and 6,227 passengers during peak hour.

The Howrah-Delhi railway line traverses through the entire city length in the east-west direction. Major railway stations along main line are Patna Junction, Patna City and Rajendra Nagar Terminal.

The city is also facilitated with an Airport named Lok Nayak Jayaprakash Airport which located near Sanjay Gandhi Biological Park (Patna Zoo) and is accessible through Bailey Road, Rukunpura -Khagol road and NH 139.




Source: Prepared by JST based on Google Earth

**Figure 15-2: Metro Stations at Major Transport Nodes**

### (3) Speed and Delays Characteristics

The journey speed characteristics during peak and off-peak periods are presented in the following tables.

Journey speeds are slow in Patna. Road networks having journey speed less than 30 kmph during peak hour consisted 83% of the road length, and off-peak periods 63 %.

**Table 15-22: Distribution of Road Length by Peak Hour Journey Speed**

| S. No. | Journey Speed (Km/hr) | Road Length (Km) | Percentage (%) |
|---|---|---|---|
| 1 | <=20 | 147.1 | 55.0 |
| 2 | 21-30 | 75.1 | 28.1 |
| 3 | 31-40 | 44.2 | 16.5 |
| 4 | 41-50 | 1.0 | 0.4 |
| 5 | >50 | 0.0 | 0.0 |
| | **Total** | **267.5** | **100** |

Source: RITES Primary Surveys

**Table 15-23: Distribution of Road Length by Off-Peak Hour Journey Speed**

| S. No. | Journey Speed (Km/hr) | Road Length (Km) | Percentage (%) |
|---|---|---|---|
| 1 | <=20 | 142.0 | 53.1 |
| 2 | 21-30 | 28.4 | 10.6 |
| 3 | 31-40 | 79.7 | 29.8 |
| 4 | 41-50 | 16.9 | 6.3 |
| 5 | >50 | 0.4 | 0.2 |
| | **Total** | **267.5** | **100** |

Source: RITES Primary Surveys

### (4) Traffic Safety

Accident statistics at Crash hotspots in 2016/17 are presented in following table. More than 300 accidents occurred including 100 fatal and 155 major accidents.

**Table 15-24: Road Accidents in Patna**

| Road Location | Fatal | Major | Minor | Total |
|---|---|---|---|---|
| Bypass Road | 18 | 23 | 11 | **52** |
| NH 31 | 16 | 29 | 9 | **54** |
| Gandhi Setu | 15 | 14 | 18 | **47** |
| Bhootnath Road | 13 | 17 | 6 | **36** |
| Old Bypass | 10 | 27 | 18 | **55** |
| Chapra Patna Highway | 9 | 8 | 7 | **24** |
| Jaganpura Road | 8 | 8 | 5 | **21** |
| Gaya Gumati Line | 6 | 11 | 9 | **26** |
| Gopalpur Road | 5 | 18 | 7 | **30** |
| **Total** | **100** | **155** | **90** | **345** |

Source: CMP Patna, 2018

## 15.2 Necessity of Land Acquisition and Resettlement

The Project require lands permanently for entry/exit of stations, ventilation facilities, ramp, pier, receiving substation (RSS), and for other temporal use such as casting yards. Major part of land acquisition occurs at the planned stations. Other permanent land acquisition occurs where lamps are required within the alignment.

Residential structures, shops and vendor stalls along major roads at those station locations are to be affected

and need to be relocated. The station facilities are designed on public land as much as possible to minimize the affected structures at various places.

## 15.3 Legal Framework for Land Acquisition and Resettlement

The Acts and Policy relevant to the study are:

- The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (No. 30 of 2013).
- Bihar Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Rules, 2014
- JICA Guidelines for Environmental and Social Considerations (April 2010)

The following sections deal with these policies with a comparison and subsequently with the entitlements and eligibility for compensation and other resettlement entitlements.

### 15.3.1 Land Acquisition Act (2013)

The Land Acquisition Act (2013) (the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013) was enforced on January 1, 2014 by amending the Land Acquisition Law (1984). The table below outlines the contents of compensation and support stipulated by the Land Acquisition Act (2013). The land price determination method stipulated by the Land Acquisition Act (2013) stipulates that the market price of land with equivalent conditions in the neighbourhood should be confirmed by three methods, and the highest price of the three methods should be adopted. In addition, the price of attached assets to the land such as buildings is calculated by using the unit price of goods, which is updated every year, in the calculation method used when procuring buildings, etc. in public works projects, and is considered to be equivalent to the market price.

The Land Acquisition Act (2013) also stipulates that a consolation fee (solatium) should be added: 2 to 2.5 times of the land price; 2 times of the price of the building and other assets (as detailed in Table 15-26 Topic g). From this calculation, it can be confirmed that the compensation as stipulated in the Land Acquisition Act (2013) suffices the full replacement cost of the land, buildings and other assets.

**Table 15-25: Due Process by the Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (Land Acquisition Act 2013)**

| Article | Process |
|---|---|
| 3 | 1) LAND PLAN DRAWINGS prepared by Project Owner |
| 4 | 2) Land Plan submitted to District Administration |
| 4 | 3) District Administration issues Art. 4 Notice<br>4) State SIA survey is procured<br>5) State SIA survey is to be finished within 6 months from issuance of the Notice |
| 5 | 6) The appropriate Government shall ensure that A PUBLIC HEARING is held at the affected area (notice to the public to be published 10 to 30 days before the hearing) |
| 6 | 7) State Social Impact Assessment study report and the State Social Impact Management Plan are shared with, and reviewed by the local governments and respective institution |
| 7 | 8) The State Social Impact Assessment report is evaluated by an independent multi-disciplinary Expert Group organized by District Administration |
| 8 | 9) The District Administration shall examine the report of the Collector on the State SIA, recommend such area for acquisition which would ensure minimum adverse impact (2) |
| 11 | 10) District Administration considers that land is required for any public purpose, a preliminary notification shall be published.<br>• From the date of publication of such notification, No person shall<br>➢ make any transaction or cause any transaction of land specified in the preliminary notification or<br>➢ create any encumbrances on such land |
| 12 | 11) To determine the extent of land to be acquired, any officer shall enter and survey any land stated in the notification. |
| 14 | 12) Where a preliminary notification is not issued within twelve months from the date of appraisal of the State Social Impact Assessment report,. such report shall be lapsed |
| 15 | 13) Any person interested in any land may, within sixty days, object to the area and suitability of land proposed to be acquired; (60 days) |
| 16 | 14) The Administrator for Rehabilitation and Resettlement shall conduct a survey and undertake a State census of the affected households (1)<br>15) The Administrator shall prepare a draft State Rehabilitation and Resettlement Scheme (2)(3)<br>16) The draft State Rehabilitation and Resettlement scheme shall be made public.<br>17) A public hearing shall be conducted at the affected area. (4)(5)<br>18) The Administrator shall, on completion of public hearing submit the draft State Scheme for Rehabilitation and Resettlement to the Collector. (6) |
| 17 | 19) The Collector shall review the draft State Scheme and forward the draft State Rehabilitation and Resettlement Scheme with his suggestions to the Commissioner Rehabilitation and Resettlement for approval |
| 18 | 20) The Commissioner shall publish the approved State Rehabilitation and Resettlement Scheme |
| 19 | 21) A declaration shall be made of an area identified as the “resettlement area” for rehabilitation and resettlement and the affected households. (Article 19 Notice)<br>22) The Collector shall publish a summary of the State Rehabilitation and Resettlement Scheme along with declaration. (1)(2)<br>23) PMRCL deposits an amount, in full or part, as prescribed as the cost of acquisition of the land: (2)<br>24) Where no declaration is made within twelve months from the date of preliminary notification, the preliminary notification shall be deemed to have been rescinded:(7) |
| 20 | 25) The land to be acquired shall be marked out and measured |
| 21 | 26) Public notice is issued stating that claims to compensations and rehabilitation and resettlement may be made to the Collector.<br>27) All persons interested in the land are required to appear before the Collector for payment of compensation not in less than thirty days and not more than six months |
| 23 | 28) The Collector shall<br>➢ enquire into the objections, and into the value of the land. and<br>➢ enquire into the persons claiming the compensation |
| 25 | 29) The Collector shall make an award within a period of twelve months from the date of publication of the declaration under section 19 |

Source: Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (LARR) Act, 2013

**Table 15-26: System, Target, and Process of Compensation and Assistances Defined by Land Acquisition Act (2013)**

| Topic | Provision of the Act |
|---|---|
| a. Establishment of a specialized body | • Establishment of the national and state monitoring committees to monitor the process of land acquisition (Section 48)<br>• Authority(s) for speedy redressal of disputes relating to land acquisition (LA) and rehabilitation and resettlement (R&R) (Section 51) |
| b. Eligibility | • Title holders (landowner and registered tenants) are eligible for compensation.<br>• Those who lose their basis of livelihood by LA are eligible for rehabilitation and resettlement. |
| c. Properties for compensation | • Land, buildings attached to the land, and other things attached to the land or building |
| d. Consultation process | • Except under urgent acquisition (Section 9) and exempt cases (Section 105), the government will follow a series of steps, including social impact assessment study and public hearing to ascertain the views of affected households to be recorded and included in the report (Sections 4 and 5). |
| e. Determination of market value of land by the District Collector | • The District Collector, when assessing and determining the market value of the land, will adopt the higher value of the following (Section 26):<br>a) The market value specified in the Indian Stamp Act 1899 in the area where the land is situated; and<br>b) The average sale price for similar type of land situated in the nearest village or nearest vicinity area. |
| f. Determination of market value of assets attached to land or building | • The market value will be calculated using the same method that is used for procurement of construction of buildings and other facilities, with unit price that is updated every year by the state government. |
| g. Compensation for landowners | • (Market value of land × 1 (urban) or × 1.25 (within 30 km from urban)) +<br>(Solatium for land (Equivalent to 100% of above)) +<br>(Market value of buildings and other things attached to the land) + (Solatium for buildings (Equivalent to 100% of above))<br>In total, 【Market value of land × 2 or × 2.5】+【Market value of attached assets × 2】 will be paid to the landowners. |
| h. Rehabilitation and resettlement | • Eleven types of elements are listed in the Second Schedule.<br>• Awards include provision of housing units, land for land, choice of annuity or employment, subsistence grant for displaced households for one year, transportation cost for displaced households, one-time grant to small traders, one-time resettlement allowance, stamp duty, and registration fee. |

Source: Land Acquisition Act 1894, Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement (LARR) Act, 2013

### 15.3.2 Bihar Rules (2014)

In addition, under Section 109 of the Land Acquisition Act (2013), the Bihar State Rules came into force on October 27, 2014, with the Department of Revenue and Land Reforms in Bihar as the competent authority. The contents of the rules are shown in the following table, which outlines the process of SIA and provide for the preparation of Rehabilitation and Resettlement scheme notifying and conducting public hearing. It also provides for assessing land rates and provision of compensation entitlement matrix for the affected households which is in line with the act. There is no discrepancy with the Land Acquisition Act (2013) and the Bihar Rules.

**Table 15-27: Structure of the Bihar Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Rules, 2014**

| | |
|---|---|
| CHAPTER I | GENERAL |
| CHAPTER II | REQUISITION FOR LAND ACQUISITION |
| CHAPTER III | SOCIAL IMPACT ASSESSMENT |
| CHAPTER IV | CONSENT |
| CHAPTER V | NOTIFICATION AND ACQUISITION |
| CHAPTER VI | REHABILITATION AND RESETTLEMENT SCHEME |
| CHAPTER VII | AWARD AND COMPENSATION |
| CHAPTER VIII | REHABILITATION AND RESETTLEMENT COMMITTEE AND STATE MONITORING COMMITTEE |
| CHAPTER IX | LAND ACQUISITION, REHABILITATION AND RESETTLEMENT AUTHORITY |
| CHAPTER X | MISCELLANEOUS |

Source: Bihar Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Rules, 2014

### 15.3.3 Metro Railways (Operation and Maintenance) Act, 2002

The Article 48 of the Metro Railways Act 2002 states that any damage to any property arising out of the working of the metro railway shall be claimed and the Claims Commissioner shall have powers to make compensation for the loss.

Any other laws, however, were not found that defines the right of underground space, and the relationship between the right of surface landownership and the right of underground space. Therefore, a metro project is not required to compensate for the use of underground space. On the other hand, the persons who own land landowner above a metro facility is not subject to any limitation in using the underground space.

For Patna Metro Rail Construction Project, underground corridors are located under major roads. Where station facilities are located in the roadside spaces, PMRCL is acquiring the land. Therefore, PMRCL is avoiding the risk of landowners digging and constructing their own underground structures that damages metro structures and systems.

### 15.3.4 JICA Guidelines

The Project is classified as "Category A" in the JICA Guidelines for of Environmental and Social Considerations (April 2010), because the Project corresponds with the railway sector which has a characteristic of large-scale involuntary resettlement.

The key principle of JICA policies on involuntary resettlement is summarized below.

1. Involuntary resettlement and loss of means of livelihood are to be avoided when feasible by exploring all viable alternatives.
2. When population displacement is unavoidable, effective measures to minimize the impact and to compensate for losses should be taken.
3. People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported so that they can improve or at least restore their standard of living, income opportunities and production levels to pre-project levels.
4. Compensation must be based on the full replacement cost as much as possible.

5. Compensation and other kinds of assistance must be provided prior to displacement.
6. For projects that entail large-scale involuntary resettlement, resettlement action plans must be prepared and made available to the public. The resettlement action plan should include elements laid out in the World Bank Safeguard Policy.
7. In preparing a resettlement action plan, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance. When consultations are held, explanations must be given in a form, manner, and language that are understandable to the affected people.
8. Appropriate participation of affected people must be promoted in planning, implementation, and monitoring of resettlement action plans.
9. Appropriate and accessible grievance mechanisms must be established for the affected people and their communities.

### 15.3.5 World Bank OP 4.12

In addition to the above core principles on the JICA policy, it also emphasized a detailed resettlement policy inclusive of all the above points; project-specific resettlement plan; the institutional framework for implementation; monitoring and evaluation mechanism; the schedule for implementation; and, detailed financial plan etc.

Additional key principle based on World Bank OP 4.12 is as follows.

1. Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including a population census that serves as an eligibility cut-off date, asset inventory, and socioeconomic survey), preferably at the project identification stage, to prevent a subsequent influx of encroachers of others who wish to take advance of such benefits.
2. Eligibility of Benefits includes the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who don't have formal legal rights to land at the time of census but have a claim to such land or assets and the PAPs who have no recognizable legal right to the land they are occupying.
3. Preference should be given to land-based resettlement strategies for displaced persons whose livelihoods are land-based.
4. Provide support for the transition period between displacement and livelihood restoration.
5. Particular attention must be paid to the needs of the vulnerable groups among those displaced, especially those below the poverty line, landless, elderly, women and children, ethnic minorities etc.
6. For projects that entail land acquisition or involuntary resettlement of fewer than 200 people, an abbreviated resettlement plan is to be prepared.

### 15.3.6 Gap with JICA Guidelines Regarding Land Acquisition and Relocation of Residents and Countermeasures

Since the Project requires land acquisition, relocation of residents, and loss of livelihood, the details of the discrepancy between JICA Guidelines on social consideration and Indian Acts and Rules, and the project policy for bridging the discrepancies are summarized in the following table.

**Table 15-28: Comparison of JICA Guidelines with Indian Acts and Rules**

| | Requirement of JICA | RFCTLARRA 2013<br>BRTFCTLARR 2014 | Gap | Policies in the 2020 SIA Entitlement Matrix and JST Proposals |
|---|---|---|---|---|
| 1 | Involuntary resettlement and loss of means of livelihood are to be avoided, when feasible, by exploring all viable alternatives. | The appropriate Government shall ensure that only the minimum area of land required for the project is proposed to be acquired. | No gap | During the study, site observation was made and alternative locations of station facilities were confirmed. PMRCL has made design changes to avoid and minimize land acquisition and resettlement to the extent possible. |
| 2 | When population displacement is unavoidable, effective measures to minimize impact and to compensate for losses should be taken. | Whenever the Government intends to acquire land for public purposes, it will carry out an SIA study that contains information on minimization of the impact, extent of remaining impact, and measures to compensate for losses. | No gap | The compensation for loss of assets will be done based on the LARRA 2013. |
| 3 | People who must be resettled involuntarily and people whose means of livelihood will be hindered or lost must be sufficiently compensated and supported so that they can improve or at least restore their standard of living, income opportunities, and production levels to pre-project levels. | In determining the amount of compensation to be awarded for land, the Collector will take into consideration the expenses to change the residence or place of business.<br>In the Second Schedule, eleven items of R&R entitlement are listed to be given in addition to the award provided by the First Schedule. | No gap | Those who were counted on the cut-off date and are to be relocated by the Project, no matter whether he/she is a title or non-title holder, will be eligible to subsistence allowance, resettlement allowance, and shifting allowance.<br>Vulnerable households will be eligible for vulnerable assistance and skills training.<br>JST proposed PMRCL, and both parties agreed that any PAHs who opted for the skills training will be provided the same. |

| | Requirement of JICA | RFCTLARRA 2013<br>BRTFCTLARR 2014 | Gap | Policies in the 2020 SIA Entitlement Matrix and JST Proposals |
|---|---|---|---|---|
| 4 | Compensation must be based on the full replacement cost as much as possible. | **Market Value of Land**<br>The Collector shall adopt the following criteria in assessing and determining the market value of the land, namely:<br>(a) the market value, if any, specified in the Indian Stamp Act, 1899 (2 of 1899) for the registration of sale deeds or agreements to sell, as the case may be, in the area, where the land is situated; or<br>(b) the average sale price for similar type of land situated in the nearest village or nearest vicinity area; or<br>(c) consented amount of compensation as agreed upon under sub-section (2) of section 2 in case of acquisition of lands for private companies or for public private partnership projects, whichever is higher<br>**Factor by which the market value is to be multiplied in the case of urban areas**<br>1 (One)<br>**Value of assets attached to land or building**<br>(1) The Collector in determining the market value of the building and other immovable property or assets attached to the land or building which are to be acquired, use the services of a competent engineer or any other specialist in the relevant field, as may be considered necessary by him.<br>(2) The Collector for the purpose of determining the value of trees and plants attached to the land acquired, use the services of experienced persons in the field of agriculture, forestry, horticulture, sericulture, or any other field, as may be considered necessary by him.<br>(3) The Collector for the purpose of assessing the value of the standing crops damaged during the process of land acquisition, may use the services of experienced persons in the field of agriculture as may be considered necessary by him.<br>**Solatium**<br>Equivalent to one hundred per cent. of the market value of land mentioned against serial number 1 multiplied by the factor specified against serial number 2 for rural areas or serial number 3 for urban areas plus value of assets attached to land or building against serial number 4 under column (2).<br>**Final award in urban areas**<br>Market Value of Land+ Value of assets attached to land or building+Solatium | The compensation is to be based on market value, not exactly the replacement cost. However, the total compensation value must be doubled by adding 100% solatium. (LARRA 2013) | The replacement value of houses, buildings, and other immovable properties will be determined on the basis of latest national Standard Schedule of Rates (SSR) as on the date without depreciation and 100% solatium will be added to the structure compensation.<br>Compensation of the land will be calculated by an equation directed by the LARRA 2013, which provides 100% solatium added to the land value. PMRCL adds one year interest rate of 12 % from the beginning. Therefore, the land and asset owner will receive 212 % of the evaluated price.<br>It can be concluded, therefore, that the size of compensation will surpass the full replacement cost. |

| | Requirement of JICA | RFCTLARRA 2013<br>BRTFCTLARR 2014 | Gap | Policies in the 2020 SIA Entitlement Matrix and JST Proposals |
|---|---|---|---|---|
| 5 | Compensation and other kinds of assistance must be provided prior to displacement. | The Collector shall take possession of land after ensuring that full payment of compensation as well as rehabilitation and resettlement entitlements are paid.<br>No land use change will be permitted if rehabilitation and resettlement is not compiled fully. | No gap | JST found 2 issues in PMRCL's policies that needs to be amended.<br>1) 50 structures (50 PAHs) have already left from public land they originally occupied on May 2020 without receiving compensation or assistances. JST and PMRCL agreed that PMRCL shall identify the 50 PAHs using ID information obtained during the SIA survey and pay compensation and provide R&R assistances.<br>2) DPR SIA states that '80% compensation is paid prior to displacement and 100% compensation before commencement of civil works.'<br>In the letter dated Sep. 21, 2022 (Point 2 and 5), PMRCL agreed that 100 % compensation and other assistances to be provided to PAHs prior to displacement. |
| 6 | For projects that entail large- scale involuntary resettlement, RAPs must be prepared and made available to the public. | BRFCTLARR 2014 requires that:<br>The draft Rehabilitation and Resettlement Scheme will be widely published in the affected areas through the Official Gazette, newspapers, in the local government offices, the website of the government, and on a public notice in the affected areas.<br>The final SIA Report and SIMP shall be prepared in the local language and shall be made available to Municipal Corporation, and the offices of the District Collector, the Sub-Divisional Officer, and shall be uploaded on the website of the appropriate Government.<br>(Section 16 of Act 2013 i.e. "Preparation of Rehabilitation and Resettlement Scheme by the Administrator") | No gap | District of Patna, on behalf of State of Bihar, is under process of land acquisition, including preparation of the SIA Report, and resettlement and rehabilitation plan for the Project.<br>JST reviewed those SIA reports and Resettlement Policy Framework prepared by PMRCL to confirm that the whole project scope is included, the entitlement matrix fulfils the requirements of the JICA Guidelines, and the reports and plans are made available to the public. |
| 7 | In preparing RAPs, consultations must be held with the affected people and their communities based on sufficient information made available to them in advance. | Whenever an SIA is required, the appropriate Government shall ensure that a public hearing is held at the affected area after giving adequate publicity about the date, time, and venue for the public hearing.<br>(Section 16 of Act 2013 i.e. "Preparation of Rehabilitation and Resettlement Scheme by the Administrator") | No gap | PMRCL engineer disseminated the project information to the affected communities in the public consultations in DPR preparation phase in 2020.<br>District Administration of Patna, on behalf of State of Bihar, is under process of preparing the SIA Report and resettlement and rehabilitation plan for the Project.<br>JST reviewed the information disseminated in preparation phase in 2020 and confirmed that sufficient information was disseminated in the early phase of the consultation.<br>During the study, JST confirmed that, according to the requirement of the Land Acquisition Act 2013, District Administration is implementing consultations with the affected landowners and other stakeholders to prepare the SIA reports and the resettlement plans. |
| 8 | When consultations are | Whenever an SIA is required, the appropriate Government shall ensure that a public hearing | No gap | The consultations were held using Hindi, and the State SIA reports were |

| | Requirement of JICA | RFCTLARRA 2013<br>BRTFCTLARR 2014 | Gap | Policies in the 2020 SIA Entitlement Matrix and JST Proposals |
|---|---|---|---|---|
| | held, explanations must be given in a form, manner, and language that is understandable to the affected people. | is held at the affected area to ascertain the views of the affected households to be recorded and included in the SIA report.<br>The SIA report is prepared and made available in the local language and will be published in the affected areas and uploaded on the website of the government.<br>(Section 16 of Act 2013 i.e. "Preparation of Rehabilitation and Resettlement Scheme by the Administrator") | | prepared in Hindi, which is the language used in basic education in Patna. |
| 9 | Appropriate participation of affected people must be promoted in planning, implementation, and monitoring of RAPs. | Whenever an SIA is required, the appropriate Government will ensure that a public hearing is held at the affected area to ascertain the views of the affected households to be recorded and included in the SIA report.<br>(Section 16 of Act 2013 i.e. "Preparation of Rehabilitation and Resettlement Scheme by the Administrator") | JICA requires PAPs participation in the implementation and monitoring phase.<br>This issue has been considered in section 45 of Act 2013. | JST proposed to PMRCL and two parties agreed on following regarding the participation of the PAPs in the implementation and monitoring phase:<br>- In the implementation phase, the implementing Committee will meet with each PAH, and custom-made micro RAP with all the needs and requests reflected will be developed and implemented.<br>- In the monitoring phase, an External Monitoring Specialist will facilitate the participatory research, target group monitoring and sample survey. |
| 10 | Appropriate and accessible grievance mechanisms must be established for the affected people and their communities. | Any person may object to the area, justification for public purpose, and the findings of the SIA report to the Collector.<br>(Section 15 of Act 2013 i.e. "Preparation of Rehabilitation and Resettlement Scheme by the Administrator") | JICA requires a grievance redress mechanism to be available throughout the resettlement process. | JST discussed with PMRCL about the grievance redress mechanism of the Project, which was not yet established in September 2022. JST confirmed that all the necessary position to establish the mechanism are already filled.<br>Until the official establishment of the GRC, the Director (Project) will assist the General Manager (Works), PMRCL in communication and coordination with the Chief Project Manager (Construction) DMRCL, in solving raised grievances. The office of the Director (Project) will be responsible for taking records of grievances and follow-up until the redressals.<br>Covered under Item 15.8.5 of this report. |
| 11 | Affected people are to be identified and recorded as early as possible in order to establish their eligibility through an initial baseline survey (including population census that serves as **an eligibility cut- off date**, asset inventory, and socio-economic survey), preferably at the project identification stage, **to prevent a subsequent influx of encroachers** of others who wish to take advantage of such benefits. (WB OP 4.12, Para. 6) | No person shall make any transaction or cause any transaction of land specified in the preliminary notification or create any encumbrances on such land from the date of publication of such notification.<br>(Section 11 of Act 2013 i.e. "Publication of preliminary notification and power of officers"). | JICA requires a cut-off date for Non-title Holders on public land. | PMRCL has made a preliminary baseline survey and produced preliminary list of the PAPs. The Survey was done in May 2020.<br>JST proposed PMRCL that, for this Project, those who were counted on the cut-off date but their residence or use of land is less than 3 years are awarded with relocation assistances and income rehabilitation by utilizing existing laws and guidelines.<br>PMRCL informed JICA that those who has less than 3 years of tenancy will be made eligible after approval of PMRCL Board.<br>State of Bihar sets the cut-off date for title holders and non-title holders on private land by issuing the preliminary notice (Article 11 Notice) to restrict transaction of the land proposed for acquisition. The cut-off date of non-title holders will be the date of the preliminary baseline survey by PMRCL (May 2022). |

| | Requirement of JICA | RFCTLARRA 2013<br>BRTFCTLARR 2014 | Gap | Policies in the 2020 SIA Entitlement Matrix and JST Proposals |
|---|---|---|---|---|
| 12 | Eligibility of benefits includes the PAPs who have formal legal rights to land (including customary and traditional land rights recognized under law), the PAPs who do not have formal legal rights to land **at the time of census** but have a claim to such land or assets, and the PAPs who have no recognizable legal right to the land they are occupying. (WB OP 4.12 Para. 15) | 'Affected Family' includes<br>(i) a family whose land or other immovable property has been acquired;<br>(ii) a family which does not own any land but a member or members of such family may be agricultural labourers, tenants including any form of tenancy or holding of usufruct right, share-croppers or artisans or who may be working in the affected area f**or three years prior to** the acquisition of the land, whose primary source of livelihood stand affected by the acquisition of land;<br>(iii) the Scheduled Tribes and other traditional forest dwellers who have lost any of their forest rights recognised under the Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act, 2006 (2 of 2007) due to acquisition of land;<br>(iv) family whose primary source of livelihood **for three years prior to t**he acquisition of the land is dependent on forests or water bodies and includes gatherers of forest produce, hunters, fisher folk and boatmen and such livelihood is affected due to acquisition of land;<br>(v) a member of the family who has been assigned land by the State Government or the Central Government under any of its schemes and such land is under acquisition;<br>(vi) a family residing on any land in the urban areas **for preceding three years or more prior to** the acquisition of the land or whose primary source of livelihood for three years prior to the acquisition of the land is affected by the acquisition of such land;<br>(Section 3 of Act 2013 i.e. "Affected family" definition.) | JICA requires all persons whose livelihood or residence will be affected by the project to be compensated, including Project Affected Households on public land, and Non-title Holders whose tenure is less than 3 years. | JST proposed PMRCL, and PMRCL is under internal processing that, for this Project, informal settlers (residential and commercial) who were counted on the cut-off date but their residence or use of land is less than 3 years are awarded with compensation, relocation assistances and income rehabilitation.<br>Already covered under Item No 2, 3, 4 5, of Entitlement matrix (Table15-66). |
| 13 | Preference should be given to land-based resettlement strategies for displaced persons whose livelihoods are land-based. (WB OP 4.12 Para. 11) | The Second Schedule stipulates land for land compensation is made available for landowners owning agricultural land in the affected area and whose land has been acquired or lost.<br>(The Second Schedule of the Act 2013 i.e. "Land for Land serial No 2"). | Not applicable | The DPR compensation plan proposes cash compensation for the loss of land for landowners, and three months (90 days) advance notification for the harvesting of standing crops, or lump sum equal to the market value of the yield of the standing crop lost determined by Agricultural Department.<br>JST reviewed the State SIA reports, and confirmed that there are no agriculture tenants affected by the project. |

| | Requirement of JICA | RFCTLARRA 2013<br>BRTFCTLARR 2014 | Gap | Policies in the 2020 SIA Entitlement Matrix and JST Proposals |
|---|---|---|---|---|
| 14 | Provide support for the transition period (between displacement and livelihood restoration). (WB OP 4.12 Para. 6) | The Second Schedule stipulates as support for the transition period, all the affected households will be eligible for the following: choice of annuity or employment subsistence grant for displaced households for a period of one year (monthly subsistence), and one-time resettlement allowance.<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 4 & 5"). | No gap | Those who were counted on the cut-off date and who need to be relocated due to the Project, regardless of whether he/she is a title holder or non-title holder, will be eligible to subsistence allowance, resettlement allowance, and shifting allowance.<br>Vulnerable households will be eligible for vulnerable assistance and skills training. |
| 15 | Particular attention must be paid to the needs of the vulnerable groups among those displaced, especially those below the poverty line, landless, elderly, women, children, ethnic minorities, etc. (WB OP 4.12 Para. 8) | As far as possible, no acquisition of land will be made in the scheduled areas. In case of acquisition, special provisions will be provided for Scheduled Castes and Scheduled Tribes.<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 7"). | JICA requires consideration for not only Scheduled Castes and Scheduled Tribes but for all vulnerable groups. | In DPR/SIA Entitlement Matrix, Vulnerable PAPs are defined as those living below poverty line, SC/ST households and women-headed households, differently abled persons are among the affected households.<br>JST proposed PMRCL and two party agreed to include elderly households above the age of 60 years without support from other family members in the list for additional assistances. |

Source: JST

## 15.4 Summary of Land Acquisition, Resettlement and Relocation

Total permanent land requirement for the Project is 47.625 ha (public 11.930 ha, private 35.695 ha). Total 15.764 ha, 11.930 ha of Central or State government land and 3.834 ha of private land will be used for stations and related facilities such as ventilation and entrances. To minimize the impact on private land, the station facilities are planned on government land and under the existing artery roads as much as possible. Public land is to be transferred to PMRCL from original owner institutions such as National Highway Authority of India, Road Construction Department and Revenue and Land Reforms Department of State of Bihar. 31.861 ha of private land is to be acquired for the Depot. Temporal land use, expected to be 29.167 ha, is planned on government land only.

Land requirement at various locations is summarized in table below.

## Table 15-29: Summary of Land Acquisition, Resettlement and Relocation

**Corridor-1**

| Elevated/ Under | Corridor & Station No. | Station Name | JICA Funding[1)] | Title Holder | NOC for Gov. Land[2)] | LARRA process[3)] | Construction Works | No. Fully Affected Structures July 2022 | No. Fully Affected PAHs July 2022 | Government Land (Permanent) (ha)[4)] | Government Land (Temporal) (ha)[4)] | Private Land (Permanent) (ha)[4)] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Elevated | 1-1 | Danapur | - | Public only | Ongoing | | PC04 Started 2022 Jan/10 | | | 0.111 | | |
| Elevated | 1-2 | Saguna More | - | Public only | Granted | | | | | 2.534 (Include area For Rama Krishna Nagar) | | |
| Elevated | 1-3 | RPS More | - | Public only | Granted | | | | | | | |
| Elevated | 1-4 | Patliputra | - | Public only | Granted | | | | | | | |
| Under | 1-5 | Rukanpura | Y (PC6) | Private/Public | Granted | SIA | | 2 | 3 | | | 0.410 |
| Under | 1-6 | Rajabazar | Y (PC6) | Private/Public | Granted | SIA | | 3 | 4 | 0.173 | | 0.517 |
| Under | 1-7 | Patna Zoo | Y (PC5, 6) | Public only | Granted | | | 8 | 23 | 0.090 | 0.029 | |
| Under | 1-8 | Vikas Bhawan | Y (PC5) | Public only | Ongoing | | | | | 0.257 | 0.079 | |
| Under | 1-9 | Vidyut Bhawan | Y (PC5) | Public only | Ongoing | | | | | 0.136 | 0.117 | |
| Under | 1-10 (2-1) | Patna Junction | Y (PC5) | Private/Public | Ongoing | SIA | | | | 0.254 | 0.156 | 0.025 |
| Under/Elevated | 1-11 | Mithapur | - | Private/Public | Ongoing | SIA | PC04 Started 2022 Jan/10 | | | 1.541 | 0.237 | 0.584 |
| Up | 1-12 | Ramakrishna Nagar | - | Private/Public | Granted | SIA | | | | (shown above) | | 0.070 |
| Up | 1-13 | Jaganpura | - | Private/Public | Granted | SIA | | | | | | 0.058 |
| Up | 1-14 (2-9) | Khemni Chak | - | Private/Public | Granted | SIA | PC01 Started 2020 Sep.28. | | | (Corridor2) | | (Corridor2) |
| | PC-04 Casting Yard | | - | Public only | Granted | | | | | | 5.000 | |
| | PC-05 Casting Yard | | Y (PC5) | Public only | - | | | | | | 5.000 | |
| | PC-06 Casting Yard | | Y (PC6) | Public only | - | | | | | | 5.000 | |
| | Waste Plant & Dumping Yard | | - | Public only | Granted | | | | | | 4.368 | |
| **Corridor1 Total (ha)** | | | | | | | | **13** | **30** | **5.095** | **19.986** | **1.664** |

1) Shows locations of Civil Work parckages to be funded by JICA. Other JICA funding is planned for items such as track works, electrical works, procurement of rolling stock, and signal and telecom works.

2) Source: Monthly progress report, August 2022, DMRCL

3) Process of private land purchase matures in the order starting from SIA phase to Art. 11 Notice phase to Art. 19 Notice phase. In Art. 19 Notice phase, District Administration is ready to start negotiation of the compensation package and payment to PAH.

4) Source: JST based on PMRCL (Land details as per July 2022)

**Corridor-2**

| Up/Under | Station No. | Station Name | JICA Funding[1)] | Title Holder | NOC for Gov. Land[2)] | LARRA process[3)] | Construction Works | No. Fully Affected Structures July 2022 | No. Fully Affected PAHs July 2022 | Government Land (Permanent) (ha)[4)] | Government Land (Temporal) (ha)[4)] | Private Land (Permanent) (ha)[4)] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Under | 2-1(1-10) | Patna Junction (reshown) | - | Private/Public (reshown) | Ongoing | SIA | | | | (Corridor1) | (Corridor1) | (Corridor1) |
| Under | 2-2 | Akashwani | - | Private/Public | Granted | SIA | | 5 | 8 | 0.149 | 0.031 | 0.068 |
| Under | 2-3 | Gandhi Maidan | - | Public only | Granted | | PC02 Started 2022 Jan/10 | 6 | 9 | 0.201 | 0.289 | |
| Under | 2-4 | PMCH | - | Private/Public | Granted | SIA | | 3 | 3 | 0.462 | 0.334 | 0.111 |
| Under | 2-5 | University | - | Private/Public | Ongoing | SIA | | | | 0.215 | 0.660 | 0.041 |
| Under | 2-6 | Moin-ul-Haq | - | Public only | Granted | | | | | 0.203 | 0.724 | |
| Under | 2-7 | Rajendra Nagar | - | Public only | Ongoing | | | | | 0.278 | 0.015 | |
| Elevated | 2-8 | Malahi Pakri | - | Public only | Granted | | PC01 Started 2020 Sep.28. | 41 | 41 | 1.335 | 0.128 | |
| Elevated | 2-9(1-14) | Khemni Chak (reshown) | - | Private/Public (reshown) | Granted | SIA | | 4 | 4 | 3.580 | | 0.238 |
| Elevated | 2-10 | Bhootnath | - | Public only | Granted | | | 2 | 2 | 0.100 | | |
| Elevated | 2-11 | Zero Mile | - | Public only | Ongoing | | | 2 | 2 | 0.177 | | |
| Elevated | 2-12 | New ISBT | - | Private/Public | Ongoing | Art.19 Notice | | | | 0.136 | | 1.713 |
| Level(raised) | | Depot | - | Private only | | Art.19 Notice | | 2 | 2 | | | 31.861 |
| | PC-03 Casting Yard | | - | Public only | Granted | | | | | | 7.000 | |
| **Corridor2 Total** | | | | | | | | **65** | **71** | **6.835** | **9.180** | **34.031** |

1) Shows locations of Civil Work parckages to be funded by JICA. Other JICA funding is planned for items such as track works, electrical works, procurement of rolling stock, and signal and telecom works.
2) Source: Monthly progress report, August 2022, DMRCL
3) Process of private land purchase matures in the order starting from SIA phase to Art. 11 Notice phase to Art. 19 Notice phase. In Art. 19 Notice phase, District Administration is ready to start negotiation of the compensation package and payment to PAH.
4) Source: JST based on PMRCL (Land details as per July 2022)

## 15.5 Scale and Extent of Resettlement

PMRCL, the Project Owner, implemented SIA study in 2020 as a part of the Detailed Project Report for approval of the Project by the State of Bihar. After the approval of the Project by the State of Bihar, the State of Bihar takes responsibility of acquiring the land for the Project following the 2013 Land Acquisition Act. The process of land acquisition includes an independent SIA survey procured by the Patna District Administration on behalf of the State of Bihar.

Since the State SIA survey contains updated information about the land owners, information in the State SIA reports were used in Sections 15.5 and 16.2.2 to review and analyze updated condition of the Project.

### 15.5.1 Update of Scale and Extent of Land Acquisition

#### (1) Land Requirement

The latest land requirement is shown in the table below. In total, permanent land requirement is 47.63 ha, and temporal land requirement is 29.17 ha. Private land is required only for permanent purpose.

**Table 15-30: Updated Land Requirement for Corridor-1 and Corridor-2 at July 2022 (in ha)**

| Sr. No | Item | Unit | Corridor1 | Corridor2 | Total |
|---|---|---|---|---|---|
| **1** | **Government Land** | | | | |
| 1.1 | Permanent | ha | 5.095 | 6.835 | 11.930 |
| 1.2 | Temporary | ha | 19.986 | 9.180 | 29.166 |
| 1.3 | Total Government Land | ha | 25.081 | 16.015 | 41.096 |
| **2** | **Private Land** | | | | |
| 2.1 | Permanent | ha | 1.664 | 34.031 | 35.695 |
| 2.2 | Temporary | ha | 0 | 0 | 0 |
| 2.3 | Total Private Land | ha | 1.664 | 34.031 | 35.695 |
| **3** | **Total Land Requirement** | **ha** | **26.745** | **50.046** | **76.791** |
| 4 | Total Permanent Land | ha | 6.759 | 40.866 | 47.625 |
| 5 | Total Temporary Land | ha | 19.986 | 9.180 | 29.166 |

Source: Data received from PMRCL on August 29, 2022. 'Land details as per July, 2022',

#### (2) Progress of Land Acquisition Process

As of September 2022, 11 locations, including the Depot area, private land acquisition are under process of Land Acquisition Act 2013. District Administration, on behalf of State of Bihar, is implementing the State SIA survey for all 11 locations.

Article 11 Notice and Article 19 Notice have been issued for the Depot area and for New ISBT Station. other land plots are still awaiting the approval of the State SIA study. As of September 2, 2022, PMRCL informed JST that 18 landowners for those 2 areas have already visited the District Administration Office to start the payment process of compensation.

**Table 15-31: Progress of Land Acquisition**

| Locations | Art. 11 Notice | Art. 19 Notice | Estimated expenditure amount |
|---|---|---|---|
| Depot Area | 2021.Oct.23 | 2022.May.11 | INR. 790.80 Cr.<br>(INR. 7,908 million) |
| New ISBT Sta. | 2022.Feb.10 | 2022.May. 13 | INR. 36.08 Cr.<br>(INR. 360.8 million) |
| Jaganpura Sta.<br>Ramakrishna Nagar Sta.<br>Mithapur Viaduct<br>Akashwani Sta.<br>University Sta.<br>PMCH Sta.<br>Rajabazar Sta.<br>Rukanpura Sta.<br>Patna Junction Sta. | Under preparation at the District Administration | Will be published after all process completed after Art. 11 Notice publication | To be estimated after Art. 19 Notices are published |
| Danapur Sta.<br>Saguna More Sta.<br>RPS More Sta.<br>Patliputra Sta.<br>Zoo Metro Sta.<br>Vikas Bhawan Sta.<br>Gandhi Maidan Sta.<br>Moin-ul-Haq Sta.<br>Rajendra Nagar Sta.<br>Malahi Pakri Sta.<br>Khemni Chak Sta.<br>Bhootnath Sta.<br>Zero Mile Sta. | • Only public land parcels are affected and Art. 11 and 19 Notices are not required.<br>• PMRCL is under process of being transferred the necessary land from original owner institutions, with assistance of the District Administration. | | |

Source: PMRCL 2022.Jul. 11 'Land Status as of June 2022'

### (3) Number of Affected Landowners

As per September 16, 2022, 6 State SIA reports for 11 locations of private land acquisition have been shared by the District Administration for PMRCL and JST.

According to those reports, 35.695 ha of target land is divided into 138 plots, with about 711 registered landowners. Out of those owners, 237 landowner households have cooperated for socio-economic survey of the landowners.

Following points are the limitation of the date obtained from the State SIA reports.

- The SIA experts tried to contact all the landowners registered at the District Administration Office. It was found, however, that some of those landowners were living abroad or in other parts of India and were not available for interview survey.
- The land registration at the District Administration Office is not updated, and many self-declared landowners were found during the State SIA survey. Some of those exhibited the proof of their ownership, but some did not have any proof of their ownership. Further clarification of the true title holders must be implemented by the District Administration Office before decision of the eligible person for compensation of a land plot.

- Some registered and self-declared landowners refused to cooperate in the SIA survey, refused to be photographed, and refused to sign the attendants list. The Article 77 of the 2013 Land Acquisition Act provides instruction in case part of the landowners refused negotiation or did not agree with the amount of compensation. In such case, the District Administration Collector shall deposit the amount of the compensation in the Land Acquisition and Rehabilitation and Resettlement Authority. With the completion of the deposit, land title can be transferred to PMRCL, and PMRCL will proceed with the Project.
- The data provided in the SIA reports varies by each report. Not all data was obtained from maximum 237 PAHs surveyed.
- Census date for the residential and commercial tenants, as well as for commercial workers, will be updated after the preliminary notice (Article 11 Notice) is issued. As of September 2022, survey data from SIA 2020 is the latest, and is described in Section 15.6.1 (2) and 15.6.2 of this report.

**Table 15-32: Number of Affected Land Owners Regognized in State SIA**

| | Location | Town | Land Area for Purchase (ha) | No. of Plot (Khesra) to be Affected | No. of Registered Landowner | No. of Self - Declared Landowner | No. of Surveyed Landowner Households |
|---|---|---|---|---|---|---|---|
| 1 | Depot Area | Pahadi, Ranipur | 31.861 | 85 | 615 | N/A | 111 |
| 2 | New ISBT Sta. | Pahari | 1.713 | 6 | 40 | N/A | 16 |
| 3 | Akashwani Sta. University Sta. | Moharrampur, Sandalpur | 0.109 | 5 | N/A | N/A | 15 |
| 4 | Jaganpura Sta. Ramakrishna Nagar Sta. Mithapur Viaduct | Jaganpura, Changad, Bigrahpur | 0.712 | 9 | 40 | 60 | 57 |
| 5 | Rajabazar Sta. Rukanpura Sta. Patna Junction Sta. | Salempur Khajpura, Sadikpur Patna Municipality | 0.952 | 23 | 55 | 75 | 38 |
| 6 | PMCH Sta. | Muharrampur | 0.111 | 10 | 1 (Institutional) | 0 | (18 commercial tenants) |
| | Final Total | | **35.695** | **138** | **711** | **135** | **237** (excluding 18 commercial tenants) |

N/A: Information not available in State SIA report
Land Area: Source: PMRCL 2022.Jul. 11 'Land Status as of June 2022'
Source: SIA reports, Patna District Administration.

### 15.5.2 Profile of Project affected Landowners

According to those reports, 32.9 ha of target land is divided into 128 plots, with about 710 registered landowners own the targeted 32.9 ha of land. Out of those owners, 237 landowners cooperated for socio-economic survey. The results of the survey are summarized in following tables. Since the District Administration procured multiple experts to implement the SIA surveys, availability of data varies depending on the reports.

In following tables, the number 1 to 6 represents the locations of the surveyed stations;

**Table 15-33: State SIA Report, Target Station, and Located Town**

| Report Number | Location (Covered in State SIA report) | Town |
|---|---|---|
| 1 | Depot Area | Pahadi, Ranipur |
| 2 | New ISBT Sta. | Pahari, |
| 3 | Akashwani Sta. | Moharrampur, Sandalpur |
| | University Sta. | |
| 4 | Jaganpura Sta. | Jaganpura, Changad, Bigrahpur |
| | Ramakrishna Nagar Sta. | |
| | Mithapur Viaduct | |
| 5 | Rajabazar Sta. | Salempur Khajpura, Sadikpur Patna Municipality |
| | Rukanpura Sta. | |
| | Patna Junction Sta. | |
| 6 | PMCH | Muharrampur |

Source: JST

### (1) Social Class

Out of the 199 landowner households from whom data was obtained, 194 households were Hindus. More than half of the households belong to general groups. Households belonging to the Scheduled Castes were found at Depot area (Report 1) and area for Jaganpura Sta., Ramakrishna Nagar Sta., and Mithapur Viaduct (Report 4). Relatively large number of households belonging to the extremely backward classes, and the other backward classes were also found in the same areas.

**Table 15-34: Social Class of Affected Landowners in State SIA**

| Social Class | Report 1 | Report 2 | Report 3 | Report 4 | Report 5 | Report 6 | Total | % |
|---|---|---|---|---|---|---|---|---|
| Hindu | 110 | 15 | 12 | 57 | N/A | 0 | 194 | 97.5% |
| Schedule caste | 1 | 0 | 0 | 4 | N/A | 0 | 5 | 2.5% |
| Extremely backward class | 4 | 2 | 0 | 5 | N/A | 0 | 11 | 5.5% |
| Other backward class | 21 | 6 | 3 | 36 | N/A | 0 | 66 | 33.2% |
| General | 84 | 7 | 9 | 12 | N/A | 0 | 112 | 56.3% |
| Others | 1 | 1 | 3 | 0 | N/A | (1)* | 5 | 2.5% |
| Total surveyed PAH | 111 | 16 | 15 | 57 | (38)** | (1)* | 199 | 100.0% |

* : Institutional landowner (Bihar State Sunni Waqf Board). Excluded from the total and further analysis of landowner PAHs.
** : 38 PAHs were surveyed in the SIA but information of the social class was not described in the SIA report.
Source: JST

### (2) Type of Family

Out of the 237 landowner households from whom data was obtained, about 64 %, or 151 households, were found as nuclear family household. About 34 %, or 80 households, were found as joint family.

**Table 15-35: Type of Family of Affected Landowners in State SIA**

| Type of family | Report 1 | Report 2 | Report 3 | Report 4 | Report 5 | Report 6 | Total | % |
|---|---|---|---|---|---|---|---|---|
| Single | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0.4% |
| Nuclear | 74 | 12 | 12 | 41 | 12 | 0 | 151 | 63.7% |
| Joint | 35 | 3 | 0 | 16 | 26 | 0 | 80 | 33.8% |
| Other | 1 | 1 | 3 | 0 | 0 | 0 | 5 | 2.1% |
| **Total surveyed PAH** | **111** | **16** | **15** | **57** | **38** | **0*** | **237** | **100.0%** |

* : 1 institutional landowner was surveyed (Bihar State Sunni Waqf Board)

Source: JST

### (3) Source of Drinking Water

Asked about the source of drinking water, majority of the PAHs at Jaganpura Sta., Ramakrishna Nagar Sta., and Mithapur Viaduct (Report 4) answered as tap water, and it can be understood that the area is most urbanized area among the stations. In other areas, submersible boring well is used by majority of the households.

**Table 15-36: Source of Drinking Water of Affected Landowners in State SIA**

| Source of water | Report 1 | Report 2 | Report 3 | Report 4 | Report 5 | Report 6 | Total | % |
|---|---|---|---|---|---|---|---|---|
| Submersible (Boring) | 87 | 13 | 15 | 0 | N/A | N/A | 115 | 57.8% |
| Tap water | 6 | 1 | 0 | 54 | N/A | N/A | 61 | 30.7% |
| Only hand pump | 17 | 2 | 0 | 3 | N/A | N/A | 22 | 11.1% |
| Other | 1 | 0 | 0 | 0 | N/A | N/A | 1 | 0.5% |
| **Total** | **111** | **16** | **15** | **57** | **N/A** | **N/A** | **199** | **100.0%** |

Source: JST

### (4) Available Sanitary Services

Asked about sanitary facilities and services, almost all households have toilet. About 90 % of households have drainages. On the other hand, access to waste disposal service is still not available for about 20 % of the landowners at the Depot area. Since only 2 households are residing on the Depot area, majority of the landowners at the Depot area are non-resident landowners. The locations of those non-resident landowners are not included in the SIA report.

**Table 15-37: Provision of Toilet Facility and Source of Sanitation in the Residential Premises of Affected Landowners in State SIA**

| Source of sanitation | Provision of toilet | | Disposal of waste | | Provision of drainage | |
|---|---|---|---|---|---|---|
| | Yes | No | Yes | No | Yes | No |
| Report 1 | 111 | 0 | 82 | 29 | 98 | 13 |
| Report 2 | 16 | 0 | 15 | 1 | 15 | 1 |
| Report 3 | 15 | 0 | 15 | 0 | 15 | 0 |
| Report 4 | 56 | 1 | N/A | N/A | N/A | N/A |
| Report 5 | N/A | N/A | N/A | N/A | N/A | N/A |
| Report 6 | 1 | 0 | N/A | N/A | N/A | N/A |
| **Total** | **199** | **1** | **112** | **30** | **128** | **14** |
| % | 99.5% | 0.5% | 78.9% | 21.1% | 90.1% | 9.9% |

Source: JST

### (5) Annual Household Income

Annual household income differed largely depending on the surveyed locations. Most of the surveyed households earn over INR. 1,000,000 per year at Akashwani Sta. and University Sta. (Report 3). Most of the households who claimed annual income up to INR. 300,000 were found at Depot area (Report 1) and area for Jaganpura Sta., Ramakrishna Nagar Sta., and Mithapur Viaduct (Report 4), where relatively large number of households belonging to the Scheduled Castes, the extremely backward classes, and the other backward classes were found.

**Table 15-38: Annual Income of Affected Landowners in State SIA**

| Annual income | Report 1 | Report 2 | Report 3 | Report 4 | Report 5 | Report 6 | Total | % |
|---|---|---|---|---|---|---|---|---|
| Up to INR. 300,000 (-25,000/month)) | 19 | 4 | 0 | 16 | N/A | -** | 39 | 19.7% |
| Up to INR. 500,000 (-41,667/month) | 31 | 11 | 0 | 12 | N/A | -** | 54 | 27.3% |
| Up to INR. 1,000,000 (-83,333/month) | 36 | 0 | 1 | 29 | N/A | -** | 66 | 33.3% |
| Above INR. 1,000,000 (83,333/month-) | 24 | 1 | 14 | 0 | N/A | -** | 39 | 19.7% |
| **Total** | **110*** | **16** | **15** | **57** | **N/A** | **-**** | **198** | **100.0%** |

* : 1 Household did not provide the data.
** : 1 institutional landowner was surveyed. Income data is not applicable.

Source: JST

### (6) Occupation

For 199 households, total 370 person were found as working member. On average, 1.86 person, are working in each household.

Sixty persons in landowner households were found working for farming at the Depot area, and 5 persons at New ISBT Sta.. The purpose of farming plays supporting role in household income, with prime income coming from another member of household working in service or business sector or other livelihood. No farming tenants were found in those areas.

**Table 15-39: Occupation of Affected Landowners in State SIA**

| Occupation | Report 1 | Report 2 | Report 3 | Report 4 | Report 5 | Report 6 | Total | % |
|---|---|---|---|---|---|---|---|---|
| Farming | 60 | 5 | 0 | 0 | N/A | 0 | 65 | 17.6% |
| Service | 88 | 7 | 7 | 17 | N/A | 0 | 119 | 32.2% |
| Business | 30 | 19 | 19 | 38 | N/A | 0 | 106 | 28.6% |
| Other livelihood (i.e. Rent, Annuity) | 24 | 24 | 9 | 2 | N/A | 1* | 59 | 15.9% |
| Total number of working members | 202 | 39 | 35 | 94 | N/A | 0 | 370 | 100.0% |
| **Total** | **111** | **16** | **15** | **57** | **N/A** | **1** | **199** | **1.86** |

* : 1 institutional landowner, Bihar State Sunni Waqf Board, is a corporate body established in 1948, under provision of Central and the State acts, for the better administration of islam persons who are minority group in India. The board provides protection, supervision of the people, and administrate and utilize properties for social, economical and educational upliftment of Muslim community.

Source: JST

### (7) Preferred Measure of Compensation

Asked about the preferred measure of compensation, 84% of the affected households preferred cash payment. Preference of cash payment was observed at the locations where existing farming activities were found, i.e. the Depot area (Report 1) and New ISBT Sta. area (Report 2).

**Table 15-40: Preferred Measure of Compensation of Affected Landowners in State SIA**

| Preferred measure of compensation | Report 1 | Report 2 | Report 3 | Report 4 | Report 5 | Report 6 | Total | % |
|---|---|---|---|---|---|---|---|---|
| Money | 87 | 12 | 14 | N/A | 38 | N/A | 151 | 83.9% |
| Land/structure | 12 | 2 | 1 | N/A | 2 | N/A | 17 | 9.4% |
| Employment | 12 | 2 | 0 | N/A | 16 | N/A | 30 | 16.7% |
| Skill Development | 0 | 0 | 0 | N/A | 0 | N/A | 0 | 0.0% |
| **Total** | **111** | **16** | **15** | **N/A** | **38** | **N/A** | **180** | **100.0%** |

Source: JST

### (8) Possible Use of the Received Compensation

Asked about the possible use of the received compensation, majority of the PAHs at the Depot area (Report 1) answered interest on land purchase for agriculture. But the idea of purchasing or investment on residential plot was also popular among the PAHs at the Depot area (Report 1) and New ISBT Sta. area (Report 2). In other areas (Akashwani Sta. and University Sta. (Report 3), Rajabazar Sta., Rukanpura Sta., Patna Junction Sta. (Report 5)), business investment was the most popular idea among the PAHs.

**Table 15-41: Possible Use of the Received Compensation**

| Possible use of the amount received | Report 1 | Report 2 | Report 3 | Report 4 | Report 5 | Report 6 | Total | % |
|---|---|---|---|---|---|---|---|---|
| Land purchase for agriculture | 77 | 1 | 0 | N/A | 0 | N/A | 78 | 43.8% |
| Investment in agriculture | 0 | 0 | 0 | N/A | 0 | N/A | 0 | 0.0% |
| Building a house | 5 | 2 | 0 | N/A | 2 | N/A | 9 | 5.1% |
| Household expenditure | 0 | 0 | 0 | N/A | 0 | N/A | 0 | 0.0% |
| Marriage | 2 | 2 | 0 | N/A | 0 | N/A | 4 | 2.2% |
| Debt payment | 0 | 0 | 1 | N/A | 3 | N/A | 4 | 2.2% |
| Deposit in bank | 4 | 0 | 0 | N/A | 0 | N/A | 4 | 2.2% |
| Business investment | 0 | 0 | 11 | N/A | 35 | N/A | 46 | 25.8% |
| Other (i.e. purchase/ investment on residential plot) | 21 | 11 | 1 | N/A | 0 | N/A | 33 | 18.5% |
| **Total** | **109** | **16** | **13** | **0** | **40** | **0** | **178** | **100.0%** |

Source: JST

### (9) Main Concern of Affected Landowners

92 % of the landowners are concerned that they receive less compensation than they expect.

**Table 15-42: Main Concern of Affected Landowners in State SIA**

| Main concern regarding the land to be acquired | Report 1 | Report 2 | Report 3 | Report 4 | Report 5 | Report 6 | Total | % |
|---|---|---|---|---|---|---|---|---|
| Delay in receiving compensation | 4 | 4 | 3 | N/A | N/A | 1 | 12 | 8.4% |
| Receiving less compensation than expected | 107 | 12 | 12 | N/A | N/A | 1 | 132 | 92.3% |
| **Total** | **111** | **16** | **15** | **N/A** | **N/A** | **1** | **143** | **100.0%** |

Source: JST

### (10) Comparison of Land Prices

Three reports have information on the land prices claimed by the landowner as market price of their land. The total amount for the land to be acquired calculated using the governmental Minimum Value Rate (MVR) and the land prices claimed by the landowner are shown in the table below.

The compensation for the land will be calculated following the instruction of the Land Acquisition Act 2013, which mandates that the Government must pay 100 % solatium, and 12 % annual inflation rate. Therefore, all the landowners will receive 2.12 times value of MVR. When compared to this solatium added MVR value and the value claimed by the landowners, it was found that the value claimed by the landowners are much higher from 198% to 4141 % of the solatium added MVR value, except the value claimed at the PMCH Station (Report 6).

**Table 15-43: Comparison of Land Prices: MVR, With Solatium, Claimed Value by Owners**

| | | | a | b=a x 2.12 | c | d=c/b |
|---|---|---|---|---|---|---|
| | Location | Town | Present Cost of land based on MVR In INR. | Interim Compensation Cost of land with Solatium (MVR x 2.12) (INR) | Market Value of Land Claimed by PAHs in INR | Comparison (c/b) |
| 1 | Depot Area | Pahadi | 2,788,225,000 | 5,911,037,000 | 15,329,000,000 | 2.59 |
| | | Ranipur | 856,350,000 | 1,815,462,000 | 3,593,076,923 | 1.98 |
| 2 | New ISBT Sta. | Pahari, | 39,894,520 | 84,576,382 | 489,798,400 | 5.79 |
| 3 | Akashwani Sta. University Sta. | Moharrampur, Sandalpur | 4,913,278 | 10,416,148 | 431,344,000 | 41.41 |
| 4 | Jaganpura Sta. Ramakrishna Nagar Sta. Mithapur Viaduct | Jaganpura, Changad, Bigrahpur | N/A | N/A | N/A | N/A |
| 5 | Rajabazar Sta. Rukanpura Sta. Patna Junction Sta. | Salempur, Sadikpur, Moharrampur | N/A | N/A | N/A | N/A |
| 6 | PMCH Sta. | Muharrampur | 37,875,600 | 80,296,272 | 56,813,400 | 0.71 |

MVR: Minimum Value Rate, Land price

Source: JST based on State SIA reports

The Minimum Value Rate (MVR) (also called the circle rate, or the ready reckoner rate) of a property is the minimum value at which the property may be transacted at. This value acts as a price floor for transactions of the property. If the transaction value for the property is found to be below the circle rate of the area, the

stamp duty and registration fees for that transaction are calculated based on the circle rate, and not the transaction amount.

The MVR is calculated based on the infrastructural development or the property's worth, as well as the market rates for plots in the same neighbourhood/area and use other factors, including the below, to find out the land value.

- Condition of the land
- Infrastructure development in the area (size of roads, connectivity, transportation availability)
- Presence of amenities like schools and hospitals in the area
- Designated land use of the plots (urban/development, agriculture)

Based on the Land Acquisition Act 2013, the compensation for the land and structure will be multiplied by 2.12 to add on the solatium for the original owner. The values of land claimed by the landowner PAHs, which are shown in the table above, are more than the double of the compensation price with the solatium. It is understandable that all the SIA experts involved in the survey states that the demands of the landowners are exaggerated.

When the District Administration considers the amount of compensation for the land, structure, and any attached assets, the highest price among the following 3 different values will be considered as the market value following the instruction by the Article 26 of the Land Acquisition Act 2013.

(a) the market value, if any specified in the Indian Stamp Act, 1899 for the registration of sale deeds or agreements to sell. As the case may be. In the area, where the land is situated (MVR) ; or

(b) the average sale price for similar type of land situated in the nearest village or nearest vicinity area; or

(c) in case of acquisition of lands for private companies or for public private partnership projects, consented amount of compensation as agreed upon.

### (11) Anticipation about Impact of the Project

Out of the 6 State SIA reports, 3 reports used same questionnaire to understand the perception of the 141 landowners about project impacts.

#### 1) Economic Impact

Asked about economic impacts, negative impacts on farming activities because of the loss of farming land are anticipated by the PAHs during and after construction. On the other hand, positive economic impacts are anticipated by majority of the PAHs on increase of land price as well as on non-agriculture commercial activities and businesses after construction.

**Table 15-44: Perception about Impact of the Project: Economic Impact**

| Economic impact | | Pre construction | | | During construction | | | After construction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Neutral | Positive | Negative | Neutral | Positive | Negative | Neutral | Positive | Negative |
| 1 | Impact on farming activities | 138 | 4 | 0 | 94 | 0 | **48** | 78 | 0 | **66** |
| 2 | Impact on Non-Agriculture Commercial Activities | 125 | 16 | 1 | 113 | 22 | 7 | 12 | **130** | 0 |
| 3 | Impact on daily wage income | 138 | 4 | 0 | 117 | 8 | 17 | 100 | 24 | 18 |
| 4 | Employment impact | 139 | 3 | 0 | 92 | 13 | **63** | 79 | 24 | 39 |
| 5 | Effects of change in work area | 140 | 2 | 0 | 127 | 1 | 14 | 106 | 40 | 6 |
| 6 | Impact on Agricultural Produce Marketing | 141 | 1 | 0 | 133 | 8 | 1 | 58 | **83** | 1 |
| 7 | Impact on non-agribusiness/industry | 141 | 0 | 0 | 133 | 8 | 1 | 25 | **114** | 3 |
| 8 | Impact on Marketing of Dairy/Poultry Products | 141 | 0 | 0 | 136 | 5 | 1 | 54 | **87** | 1 |
| 9 | Impact on land price | 93 | **48** | 1 | 24 | **117** | 1 | 29 | **112** | 1 |
| 10 | Effect of economic package / amount / compensation for rehabilitation | 142 | 0 | 0 | 138 | 4 | 0 | 123 | 19 | 0 |

Source: JST based on State SIA reports (Report 1, 2, 3)

### 2) Impact on Transportation

Asked about impacts on transportation, almost all PAHs are anticipating positive impacts after the construction, by operation of the metro connecting various locations in Patna. Negative impacts are anticipated by several PAHs during construction, because the construction works will require traffic control at the work areas, that may cause traffic jam in the areas.

**Table 15-45: Perception about Impact of the Project: Impact on Transportation**

| Impact on transportation | | Pre construction | | | During construction | | | After construction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Neutral | Positive | Negative | Neutral | Positive | Negative | Neutral | Positive | Negative |
| 1 | Reduction in distance | 141 | 0 | 1 | 140 | 0 | 3 | 3 | **138** | 1 |
| 2 | Better and productive time saving | 141 | 0 | 1 | 134 | 0 | 7 | 1 | **139** | 1 |
| 3 | Impact on the movement of the elderly | 141 | 0 | 1 | 134 | 0 | 7 | 1 | **140** | 1 |
| 4 | Impact on women's movement | 141 | 0 | 1 | 135 | 0 | 7 | 4 | **137** | 1 |
| 5 | Impact on the movement of the handicapped | 141 | 0 | 1 | 132 | 0 | 10 | 8 | **133** | 1 |

Source: JST based on State SIA reports (Report 1, 2, 3)

### 3) Social Impact

Asked about social impacts of the Project, majority of PAHs are anticipating positive impacts of operation of the metro on access to educational institutions, on reducing violence against women, and on crime control. On the other hand, several PAHs anticipated negative impacts of metro operation on social crime and crime control, that may be caused by increased movement of persons by the metro.

**Table 15-46: Perception about Impact of the Project: Social Impact**

| Social Impact | | Pre construction | | | During construction | | | After construction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Neutral | Positive | Negative | Neutral | Positive | Negative | Neutral | Positive | Negative |
| 1 | Impact on access to educational institutions | 142 | 0 | 0 | 134 | 1 | 7 | 9 | **132** | 1 |
| 2 | Impact on social harmony | 142 | 0 | 0 | 137 | 2 | 3 | 109 | 28 | 3 |
| 3 | Impact on social structure | 142 | 0 | 0 | 137 | 2 | 3 | 116 | 19 | 3 |
| 4 | Socio-Culture Effects on Behaviors | 142 | 0 | 0 | 137 | 2 | 3 | 117 | 14 | 3 |
| 5 | Impact on gender equality | 142 | 0 | 0 | 142 | 0 | 0 | 113 | 28 | 1 |
| 6 | Impact on social crime | 142 | 0 | 0 | 138 | 2 | 2 | 93 | 42 | 7 |
| 7 | Impact on violence against women | 142 | 0 | 0 | 140 | 1 | 1 | 53 | **86** | 4 |
| 8 | Impact on crime control | 142 | 0 | 0 | 135 | 4 | 3 | 43 | **93** | 7 |
| 9 | Impact on migration | 142 | 0 | 0 | 140 | 1 | 1 | 116 | 17 | 4 |
| 10 | Effect of displacement | 142 | 0 | 0 | 142 | 0 | 0 | 130 | 8 | 4 |
| 11 | Impact on Social/ Voluntary/ Political Organization | 142 | 0 | 0 | 142 | 0 | 0 | 140 | 2 | 0 |

Source: JST based on State SIA reports (Report 1, 2, 3)

### 4) Impact on Health

Asked about impacts on health of the Project, majority of PAHs are anticipating positive impacts of metro after construction on better access to health related facilities. Regarding the impacts on community health, negative impacts are anticipated during construction because of the air and noise pollution generated from the construction works and related traffic. Positive impacts after construction are anticipated because community members will have better access to the health related facility. Negative impacts after construction are anticipated because increased population flow may result higher risk of spread of infectious diseases.

**Table 15-47: Perception about Impact of the Project: Impact on Health**

| Impact on Health | | Pre construction | | | During construction | | | After construction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Neutral | Positive | Negative | Neutral | Positive | Negative | Neutral | Positive | Negative |
| 1 | Impact on accessibility of health related facility | 142 | 0 | 0 | 116 | 13 | 13 | 12 | **128** | 2 |
| 2 | Impact on community health | 142 | 0 | 0 | 125 | 3 | 14 | 101 | 30 | 11 |

Source: JST based on State SIA reports (Report 1, 2, 3)

### 5) Impact on Environment

Asked about impacts on environment of the Project, PAHs are anticipating negative impacts on loss of natural resources and pasture during and after construction. Positive impacts on natural resources are anticipated by some PAHs after construction because the operation of metro may reduce car traffic on road, that leads less emission of air pollution.

**Table 15-48: Perception about Impact of the Project: Impact on Environment**

| Impact on environment | | Pre construction | | | During construction | | | After construction | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Neutral | Positive | Negative | Neutral | Positive | Negative | Neutral | Positive | Negative |
| 1 | Impact on exploitation of natural resources | 142 | 0 | 0 | 65 | 4 | **77** | 75 | 17 | 55 |
| 2 | Pasture | 142 | 0 | 0 | 100 | 2 | 40 | 100 | 0 | 42 |
| 3 | Cemetery/crematorium | 142 | 0 | 0 | 142 | 0 | 0 | 142 | 0 | 0 |
| 4 | Pond | 142 | 0 | 0 | 142 | 0 | 0 | 142 | 0 | 0 |
| 5 | Playing field | 142 | 0 | 0 | 142 | 0 | 0 | 142 | 0 | 0 |

Source: JST based on State SIA reports (Report 1, 2, 3)

## 15.6 Scale and Extent of Resettlement

### 15.6.1 Update of Scale and Extent of Resettlement

#### (1) Affected Structures

The 2 Corridors are located either above or under the existing main roads. Land is required where station facilities are to be located. In DPR SIA 2020, 146 households in the 102 structures were identified to be affected. Out of the 146 PAHs, 111 PAHs cooperated for socio-economic survey. This Study use the same socio-economic survey data in DPR SIA 2020 to understand the characteristics of the PAHs.

**Table 15-49: Number and Location of Affected Structures and PAHs in DPR SIA 2020**

| S.No. | Location | Structures | Total PAHs | PAHs Surveyed |
|---|---|---|---|---|
| | **Corridor-1** | | | |
| 1 | Rukanpura | 3 | 4 | 2 |
| 2 | Raja Bazar | 6 | 18 | 17 |
| 3 | Mithapur/ Bigrahpur | 10 | 30 | 24 |
| | **Total Corridor-1** | **19** | **52** | **43** |
| | **Corridor-2** | | | |
| 1 | Akashwani | 5 | 8 | 3 |
| 2 | Gandhi Maidan | 6 | 9 | 9 |
| 3 | PMCH | 17 | 17 | 1 |
| 4 | Rajendra Nagar | 2 | 7 | 5 |
| 5 | Malahi Pakri | 41 | 41 | 41 |
| 6 | Khemni Chak Crossing | 2 | 2 | 1 |
| 7 | Khemni Chak | 4 | 4 | 4 |
| 8 | Bhootnath to Zero Mile | 2 | 2 | 2 |
| 9 | Zero Mile | 2 | 2 | 2 |
| 10 | Depot Area | 2 | 2 | 0 |
| | **Total Corridor-2** | **82** | **94** | **68** |
| | **Grand Total** | **102** | **146** | **111** |

Source: DPR SIA 2020 p.30

As shown in the next table, 33 structures among the 102 identified in 2020 were identified as Project Affected Structures in the site survey implemented in July 2022. Comparative photo album of 2020 and 2022 are shown in Attachment 16.

To minimize the impact, design changes were made and 17 structures were saved from the project impact. On the other hand, 52 structures were already cleared from the area to be affected.

Among the 52 cleared structure, 2 structures belong to the private landowners. Title holder structures on private land that were cleared before the Preliminary Notification (Art. 11 Notification) based on the Land Acquisition Act 2013 will not be compensated. The owner shall be compensated for land.

Remaining 50 structures belong to 49 non-title holders and 1 leased shop on public land. Since the Cut-Off Date for those 50 structures are May 2020, i.e. the day of the Census for DPR SIA 2020, the owners and the lessee of those structures remain as the target for the compensation, rehabilitation, and resettlement. Non-title holders already moved out from public land or private land shall be tracked down to new locations by PMRCL, and the compensation for the loss of assets shall be provided by the District Administration with funding from PMRCL. In the letter issued on September 21, 2022, PMRCL agreed that 1) those who have already moved out from the locations listed in DPR SIA 2020 will be contacted by District Administration, 2022, and 2) the payment will be started.

**Table 15-50: Update of the Number and Location of Affected Structures**

| S.No. | Location | Structures DPR SIA 2020 | Structures Remaining to be affected as of July 2022 | Reason of Change | Structures Target for RAP July 2022 |
|---|---|---|---|---|---|
| | **Corridor -1** | | | | |
| 1 | Rukanpura | 3 | 3 | | **3** |
| 2 | Raja Bazar | 6 | 5 | 1 on private land moved out (partial/owner+ tenant) | **5*** |
| 3 | Mithapur/ Bigrahpur | 10 | 9 | 1 title holder on private land moved out (full/ 5 owners) | **9*** |
| | **Total Corridor1** | **19** | **17** | | **17** |
| | **Corridor-2** | | | | |
| 1 | Akashwani | 5 | 5 | | **5** |
| 2 | Gandhi Maidan | 6 | 1 | 5 commercial on public land moved out | **6**** |
| 3 | PMCH | 17 | 3 | 14 commercial **saved** by design change (full/ tenant) | **3** |
| 4 | Rajendra Nagar | 2 | 0 | 2 commercial & R+C **saved** by design change (full/ owner+tenant) | **0** |
| 5 | Malahi Pakri | 41 | 0 | 1 commercial & 40 residential on public land moved out | **41**** |
| 6 | Khemni Chak Crossing | 2 | 1 | 1 commercial **saved** by design change (partial/ owner) | **1** |
| 7 | Khemni Chak | 4 | 4 | | **4** |
| 8 | Bhootnath to Zero Mile | 2 | 0 | 2 commercial on public land moved out | **2**** |
| 9 | Zero Mile | 2 | 0 | 2 commercial on public land moved out | **2**** |
| 10 | Depot Area | 2 | 2 | | **2** |
| | **Total Corridor2** | **82** | **16** | | **66** |
| | **Grand Total** | **102** | **33** | | **83** |

* : Structure that was cleared before the Preliminary Notification (Art. 11 Notification) based on the Land Acquisition Act 2013 will not be compensated. The owner shall be compensated for land.

** : Non-title holders already moved out from public land shall be tracked down to new locations by PMRCL, and the compensation for the loss, assistance for the relocation, and rehabilitation for the livelihood shall be provided by the District Administration with funding from PMRCL.

Source: JST based on DPR SIA 2020 p.30

As a result, the updated number of the target structures of the Project for compensation is 83 structures. (83 = 102 – 17 (saved structure) – 2 (cleared title holder structure))

**Table 15-51: Affected Structures**

| Type | Number DPR SIA 2020 | Update July 2022 | Reason of Change |
|---|---|---|---|
| | | Target for Compensation | |
| Residential: | 47 | 45 | 2 on private land already cleared |
| CIBEs(commercial, industrial and business enterprises) | 50 | 34 | 16 saved by design change |
| Residential cum ClBE: | 4 | 3 | 1 saved by design change |
| Institutional | 1 | 1 | |
| **Total** | **102** | **83** | |
| Other social infrastructure to be affected | | | |
| Temples | 5 | 5 | |
| Public toilets | 3 | 3 | |

Saved structure: 17 (16 commercial, 1 residential cum CIBE),

Removed structure before cut-off date (Article 11 Notification): 2 (both residential)

Source: Detailed Project Report 2021, RITES, Social Impact Assessment Report 2020, DMRCL, JST

Looking at the use of the affected structures, 45 residential structures and 34 commercial structures are to be affected. Looking at the magnitude of impacts, 78 structures out of total 83 will be fully affected, hence residents, shops, tenants in those structures need to be relocated. Looking at the location of the impacts, the largest number of 41 structures are affected at Malahi Pakri Station of Corridor2, followed by 9 structures at Mithapur Station and 6 structures at Gandhi Maidan Station.

**Table 15-52: Magnitude of Impacts on Structures**

| | | Fully affected | | Partly affected | | Total |
|---|---|---|---|---|---|---|
| | | Corridor1 | Corridor2 | Corridor1 | Corridor2 | |
| 1 | Residential | 2 | 42 | 1 | | 45 |
| 2 | Residential + Commercial | 2 | | | 1 | 3 |
| 3 | Commercial | 9 | 23 | 2 | | 34 |
| 4 | Institutional | | | 1 | | 1 |
| 5 | Sub-total | 13 | 65 | 4 | 1 | 83 |
| 6 | Grand-total | 78 | | 5 | | 83 |

Source: JST

**Table 15-53: Location-wise, Purpose-wise Number of Affected Structures**

| | | | Residential | Commercial | R+C | Institutional | Total |
|---|---|---|---|---|---|---|---|
| Cor.1 | 5 | Rukanpura | 2 | 1 | | | 3 |
| Cor.1 | 6 | Raja Bazar | 1 | 3 | | 1 | 5 |
| Cor.1 | 11 | Mithapur | 0 | 7 | 2 | | 9 |
| Cor.2 | 2 | Akashwani | | 5 | | | 5 |
| Cor.2 | 3 | Gandhi Maidan | | 6 | | | 6 |
| Cor.2 | 4 | PMCH | | 3 | | | 3 |
| Cor.2 | 7 | Rajendra Nagar | | 0 | 0 | | 0 |
| Cor.2 | 8 | Malahi Pakri | 40 | 1 | | | 41 |
| Cor.2 | 9 | Khemni Chak Crossing | | 0 | 1 | | 1 |
| Cor.2 | 9 | Khemni Chak Sta | | 4 | | | 4 |
| Cor.2 | 11 | Bhootnath to Zero Mile | | 2 | | | 2 |
| Cor.2 | 11 | Zero Mile | | 2 | | | 2 |
| Cor.2 | 13 | Depot Area | 2 | | | | 2 |
| **Total** | | | **45** | **34** | **3** | **1** | **83** |

Source: JST

## (2) Affected Households

The DPR SIA implemented census survey of the PAHs in the affected structures in May 2020. The survey identified 146 PAHs/PAPs (including residents, shops, institutional owners) in 102 structures as shown in Table 15-54.

Among the 146 PAHs identified in 2020, 120 HH were planned to be fully affected and expected to be resettled and relocated. The fully affected PAHs included 53 residential PAHs, 18 shop owners, 42 commercial tenants, and 7 shop lessees.

**Table 15-54: PAHs for Resettlement in DPR SIA 2020**

| | | DPR SIA | |
|---|---|---|---|
| | **Group** | **Number** | **By Tenancy** |
| 1 | Total Project Affected Households (PAHs) (Including commercial use and institution) | 146 HH / 720 persons | Title Holders: 75 HH / 370 persons |
| | | | Non-Title holders: 69 HH 340 persons |
| | **Fully Affected** | | |
| 2 | Fully Project Affected Households (PAHs) (Including commercial use and institution) | 120 HH / 591 persons | Title Holders: 69 HH / 340 persons |
| | | | Non-Title holders: 51 HH / 251 persons |
| 3 | PAHs which need to be resettled (as resident) | 53 HH / 261 persons | Title Holders: 13 HH / 64 persons |
| | | | Non-Title Holders: 40 HH / 197 persons |
| 4 | Business owners who need relocation | 18 HH / 89 persons | Title Holders: 7 HH / 35 persons |
| | | | Non-Title Holders: 8 HH / 39 persons |
| | | | Kiosk: 3 HH / 15 persons (can operate on other locations) |
| 5 | Commercial Tenants who need relocation | | 42 commercial tenant HH / 207 persons |
| 6 | Leases on Government Land who need relocation | | 7 lessee HH (can operate on other locations) / 35 persons |
| | **Partly Affected** | | |
| 7 | Partly Project Affected Households (PAHs) (Including commercial use and institution) | 26 HH / 128 persons | Title Holders: 26 HH / 128 persons |
| | | | Non-Title holders: 0 HH / 0 persons |
| 8 | PAHs who do not need to be resettled (as resident) | 5 HH / 25 persons | Title Holders: 5 HH / 25 persons |
| | | | Non-Title Holders:0 HH / 0 persons |
| 9 | Business owners who do not need relocation | 9 HH / 44 persons | Title Holders: 9 HH / 44 persons |
| | | | Non-Title Holders: 0 HH / 0 persons |
| | | | Kiosk: 0 HH / 0 persons0 |
| 10 | Commercial Tenants who do not need relocation | | 12 commercial tenant HH / 59 persons |
| 11 | Leases on Government Land who do not need relocation | | 0 lessee HH / 0 persons |

* : Average HH size is calculated from the 111 HH survey results as 4.93 person per HH. (4.92792 = 547 / 111)
** : Number of PAPs is calculated using the above average HH size.

**Title Holders:** people with formal ownership of land, residential and/or commercial tenants who have contract with the title holders, and commercial lessees who will be awarded alternate location to do business in case of relocation.

**Non-Title Holders:** people without formal ownership of land, including commercial encroachers, and residential squatters.

Source: Social Impact Assessment Report 2020, DMRCL, and JST
Source: JST based on DPR SIA 2020

Update site survey in July 2022 identified 117 PAHs/shops in 83 structures as PAHs (Table 15-55). Among the 146 affected PAHs identified in DPR SIA 2020, 22 PAHs, all commercial owners and tenants, are now not affected by the design change of location of station facilities. In addition, 2 residential structures with 7 PAHs (6 owners and 1 tenant) were not found on site in July 2022, and considered to have been moved out. In total, the survey in July 2022 found 29 fewer PAHs than found in DPR SIA 2020. (146-29=117)

Among the 117 PAHs identified in 2022, 101 HH are planned to be fully affected and expected to be resettled and relocated. The fully affected PAHs include 48 residential PAHs, 18 shop owners, 28 commercial tenants, and 7 shop lessees.

In the letter issued on September 21, 2022, PMRCL agreed that 1) the PAHs related to the structures that have already moved out from the locations listed in DPR SIA 2020 will be contacted by District Administration, and 2) the payment of the compensations, relocations and rehabilitations for the PAHs will be started.

**Table 15-55: Updated PAHs for Resettlement as of July 2022**

| | | Update July 2022 Target for Compensation | |
|---|---|---|---|
| | **Group** | **Number** | **By Tenancy** |
| 1 | Total Project Affected Households (PAHs) (Including commercial use and institution) | 117 HH / 576 persons | Title Holders: 66 HH / 325 persons |
| | | | Non-Title holders: 51 HH / 251 persons |
| | **Fully Affected** | | |
| 2 | Fully Project Affected Households (PAHs) (Including commercial use and institution) | 101 HH / 498 persons | Title Holders: 50 HH / 247 persons |
| | | | Non-Title holders: 51 HH / 251 persons |
| 3 | Resident owners who need to be resettled | 46 HH / 227 persons | Title Holders: 6 HH / 30 persons |
| | | | Non-Title Holders: 40 HH / 197 persons |
| 4 | Residential tenants who need to be resettled | 2 HH / 10 persons | Tenants: 2 HH / 10 persons |
| 5 | Business owners who need relocation | 18 HH / 89 persons | Title Holders: 7 HH / 35 persons |
| | | | Non-Title Holders: 8 HH / 39 persons |
| | | | Kiosk: 3 HH / 15 persons (can operate on other locations) |
| 6 | Commercial Tenants who need relocation | | 28 commercial tenant HH / 138 persons |
| 7 | Leases on Government Land who need relocation | | 7 lessee HH (can operate on other locations) / 35 persons |
| | **Partly Affected** | | |
| 8 | Partly Project Affected Households (PAHs) (Including commercial use and institution) | 16 HH / 79 persons | Title Holders: 16 HH / 79 persons |
| | | | Non-Title holders: 0 HH / 0 persons |
| 9 | Resident owners who do not need to be resettled | 2 HH / 10 persons | Title Holders: 2 HH / 10 persons |
| | | | Non-Title Holders:0 HH / 0 persons |
| 10 | Business owners who do not need relocation | 7 HH / 35 persons | Title Holders: 7 HH / 35 persons |
| | | | Non-Title Holders: 0 HH / 0 persons |
| | | | Kiosk: 0 HH / 0 persons |
| 11 | Commercial Tenants who do not need relocation | | 7 commercial tenant HH / 35 persons |
| 12 | Leases on Government Land who do not need relocation | | 0 lessee HH / 0 persons |

* : Average HH size is calculated from the 111 HH survey results as 4.93 person per HH. (4.92792 = 547 / 111)
** : Number of PAPs is calculated using the above average HH size.

**Title Holders:** people with formal ownership of land and structure.
**Non-Title Holders:** people without formal ownership of land, including commercial encroachers, and residential squatters.

Source: JST

No change was found in the number of affected crops and trees between the 2020 condition and the 2022condition.

**Table 15-56: Affected Crops and Trees**

| Types | Area/Number | Note |
|---|---|---|
| Rice field | 0 ha | |
| Vegetable and other agriculture field | 19.2 ha | Depot |
| Public trees (street trees, trees in parks) | 911 | Corridor1 (551) Corridor2 (360) |
| Privately owned trees, trees on private land | 0 | |
| Fruit bearing trees | 0 | |
| Timber trees, non-fruit trees | 0 | |
| Other cash trees/plants | 0 | |

Source: DPR SIA 2020, DMRCL

In 2020, out of the 146 PAHs, a total of 28 households were found to belong socially vulnerable groups. In 2022, only 4 PAHs out of 28 were remaining on site. PMRCL, however, shall track the vulnerable PAHs to new locations, and shall share the information with the District Administration for payment of additional award of rehabilitation assistances.

**Table 15-57: Vulnerable Families**

| Sr No. | Type of Vulnerable Family | Number, Location | Total in DPR, Eligible for Compensation | Update July 2022 on Site |
|---|---|---|---|---|
| 1 | Disability – Blind | 1 Malahi Pakri | 1 | 0 |
| 2 | Scheduled Castes with Below Poverty Line | 4 Malahi Pakri | 4 | 0 |
| 3 | Scheduled Castes with Women Headed Family | 3 Malahi Pakri | 3 | 0 |
| 4 | Scheduled Castes | 1 Khemni Chak,<br>14 Malahi Pakri | 15 | 1 |
| 5 | Below Poverty Line Families | 1 Bhootnath to Zero Mile,<br>1 Zero Mile | 2 | 2 |
| 6 | Women Headed Families | 1 Raza Bazar,<br>2 Malahi Pakri | 3 | 1 |
| | **Total** | | **28** | **4 (24 to be tracked)** |

Source: JST, DPR SIA 2020, DMRCL, p. 48, Annexure 3

### 15.6.2 Profile of Project affected Households

The alignment drawing and information provided by PMRCL was the basis for the identification of the affected households and project affected people due to the proposed project phase. The study represents assessment of the affected households, which includes titleholders and non-titleholders. The group of non-titleholders included tenants, squatters, kiosk owners, etc.

The interviewers interacted with the social groups involved for the purpose to disclose the information required for the questionnaires format for data collection. The survey had been conducted within the proposed Right of Way of the viaduct, station areas and the land to be acquired for the project. For the viaduct the ROW has been considered to be 11 m.

The survey has been carried out for 111 households. Demographic details of affected people have been taken from residential premises. Additionally, small shops/ Kiosks/ squatters are located in the proposed Right of Way marked on the alignment drawing.

The SIA was investigated in May 2020. The survey identified 146 households in the building located on the land to be acquired, and conducted a questionnaire survey on 111 of these households to understand the average number of household members, household income, and other socio-economic conditions. Of the 35 households not surveyed, 17 were not at home due to the COVID pandemic. In addition, 18 households did not cooperate with the survey.[53]

The socio-economic analysis of surveyed household has been presented in the following sections.

### (1) Demographic Profile of PAHs

The social survey has been carried out on 111 households. These households have 547 members. Average household size was calculated as 4.93 (547/111=4.92792) person per household. This average household size was used to estimate the number of Project Affected Persons (PAPs).

The demographic profile of PAPs covers their distribution according to religion, social castes, age, education and marital status.

Data reveals that majority of PAHs are Hindus (89.19%) followed by Muslims (9.90%) and Sikh (0.91%). In Corridor1, 83.72% PAHs are Hindus and rest 16.28% are Muslims. But in Corridor2 Hindus are 92.65% and Muslims are 5.88 % with 1.47% Sikhs.

**Table 15-58: Religion-wise Distribution of PAHs**

| S.No. | Religion | Numbers / Percentage (%) | Corridor-1 | Corridor-2 | Total |
|---|---|---|---|---|---|
| 1 | Hindu | Number | 36 | 63 | 99 |
| | | Percentage | 83.72 | 92.65 | 89.19 |
| 2 | Muslim | Number | 7 | 4 | 11 |
| | | Percentage | 16.28 | 5.88 | 9.91 |
| 3 | Sikh | Number | 0 | 1 | 1 |
| | | Percentage | 0 | 1.47 | 0.90 |
| | **Total** | Number | **43** | **68** | **111** |

Source: DPR SIA 2020, DMRCL

The caste-wise distribution of PAHs has also been studied. The distribution of PAHs as per castes has been given in the table below.

Distribution of PAHs by caste show that about 49.55% belong to Other Backward Castes and about 30.63 % belong to upper castes called General castes, and another about 19.82 % belong to Scheduled Castes.

There was no Scheduled Tribe among the PAHs.

Corridor-wise distribution shows that there are 46.51% General caste and 53.49% OBCs on Corridor-1, whereas in Corridor2, PAHs belonging to general caste are 20.59%, OBCs are 47.06% and SCs are 32.35%.

[53] At PMCH Station, commercial tenants refused to share social data citing the apprehension that the survey was made for collecting data as part of NRC (National Register of Citizens) and no amount of explanation could convince them. There were 17 such shops of seventeen households and only one family (one PAH) agreed to provide details and remaining 16 households refused. Additionally, residents of two houses at proposed depot area denied sharing of data.

**Table 15-59: Distribution of PAHs by Castes**

| S.No. | Caste | Numbers / Percentage (%) | Corridor- 1 | Corridor-2 | Total |
|---|---|---|---|---|---|
| 1 | General | Number | 20 | 14 | 34 |
| | | Percentage | 46.51 | 20.59 | 30.63 |
| 2 | OBC | Number | 23 | 32 | 55 |
| | | Percentage | 53.49 | 47.06 | 49.55 |
| 3 | SC | Number | 0 | 22 | 22 |
| | | Percentage | 0 | 32.35 | 19.82 |
| **Total** | | Number | **43** | **68** | **111** |
| | | Percentage | 100.00 | 100.00 | 100.00 |

Source: DPR SIA 2020, DMRCL

### Types of Household

Assessment of type of household indicates that about 18.91 % households are Joint households whereas about 77.47 % households are Nuclear households. There are 3.60% single person households among PAHs.

### Number of Household Members

Similarly, about 41.44% are small households having upto 4 members, 38.74% are medium size households having 5 to 7 members and 16.22 % are large households having more than 7 members. Family pattern is similar in both the corridors. There are 34 nuclear households in Corridor-1 and 52 in Corridor-2. Joint households are 9 in Corridor-1 and 12 in Corridor-2.

### Sex Ratio

There were 547 PAPs in 111 PAHs along the corridor alignment. These comprises of 299 males and 248 females thereby having sex ratio of 829 females per thousand males. Corridor wise sex wise distribution shows that sex ratio is 777 and 870 females per thousand males in Corridor-1 and Corridor-2 respectively. There are 54.66 % males and 45.34% females among PAPs.

### Age-wise Distribution

It is also found that about 64.35 % PAPs are more than 18 years and only 35.64 % are less than 18 years. The Age-wise distribution of PAPs has been given in the table below.

Age-wise distribution indicates that there are 58.87 % PAPs in working age group of 18 to 60 years. About 5.48 % are senior citizens above 60 years, and 23.40 % PAPs are in student age group between 6 to 18 years. About 12.25% PAPs are children below 6 years of age.

**Table 15-60: Distribution of PAPs According to Age**

| S.No. | Age | No./ % | Corridor-1 | Corridor-2 | Total |
|---|---|---|---|---|---|
| 1 | <6 | Number | 14 | 53 | 67 |
| | | Percentage | 6.06 | 16.77 | 12.25 |
| 2 | 6 to18 | Number | 56 | 72 | 128 |
| | | Percentage | 24.24 | 22.78 | 23.40 |
| 3 | 18-45 | Number | 110 | 145 | 255 |
| | | Percentage | 47.62 | 45.89 | 46.62 |
| 4 | 45-60 | Number | 36 | 31 | 67 |
| | | Percentage | 15.58 | 9.81 | 12.25 |
| 5 | > 60 | Number | 15 | 15 | 30 |
| | | Percentage | 6.49 | 4.75 | 5.48 |
| | Total | Number | 231 | 316 | 547 |
| | | Percentage | 100 | 100.00 | 100.00 |

Source: DPR SIA 2020, DMRCL

**Education Level**

The population distribution as per education level has been assessed. It is to be mentioned that the children below 6 years have been excluded from the calculations as they are subject to assessment of education level yet.

The distribution of PAPs according to education level is given in the table below.

The data revealed that about 22.08 % PAPs are illiterate, 17.71 % primary and 28.54% are educated up to 10th class. About 10.36% have studied up to class 11th – 12th and 21.46% are graduates and above.

In Corridor1, 24.42 % have studied till less than primary level and 32.26% have studied for up to 10th class. Graduates are more than 33.18 % in Corridor1. On the other hand, in Corridor2 graduates are only 11.79% and illiterates are 34.22%. About 18.25 % have studied between 5th to 12th class.

**Table 15-61: Distribution of PAPs According to Education Level**

| S.No. | Education | No./ % | Corridor-1 | Corridor-2 | Total |
|---|---|---|---|---|---|
| 1 | Illiterates | Number | 16 | 90 | 106 |
| | | Percentage | 7.37 | **34.22** | 22.08 |
| 2 | Primary upto 5$^{th}$ class | Number | 37 | 48 | 85 |
| | | Percentage | 17.05 | 18.25 | 17.71 |
| 3 | Between 5$^{th}$ to 10$^{th}$ class | Number | 70 | 67 | 137 |
| | | Percentage | 32.26 | 25.48 | 28.54 |
| 4 | 11$^{th}$ & 12$^{th}$ | Number | 22 | 27 | 49 |
| | | Percentage | 10.14 | 10.27 | 10.36 |
| 5 | Graduate and above | Number | 72 | 31 | 96 |
| | | Percentage | **33.18** | 11.79 | 21.46 |
| 6 | Total | Number | 217 | 263 | 480 |
| | | Percentage | 100.00 | 100.00 | 100.0 |

Source: DPR SIA 2020, DMRCL

The marital status of PAPs is given in the table below. 49.75 % PAPs are married and 3.47 % are widowed persons whereas the rest 46.80 % are unmarried. This includes unmarried persons below 18 years of age which is the minimum age of marriage as per law.

**Table 15-62: Marital Status of PAPs**

| S.No. | Marital Status | No. / % | Corridor- 1 | Corridor-2 | Total |
|---|---|---|---|---|---|
| 1 | Married | Number | 125 | 147 | 272 |
| | | Percentage | 77.64 | 76.96 | 77.27 |
| 2 | Widowed | Number | 7 | 12 | 19 |
| | | Percentage | 4.35 | 6.28 | 5.40 |
| 3 | Unmarried | Number | 29 | 32 | 61 |
| | | Percentage | 18.01 | 16.75 | 17.33 |
| | **Total** | **Number** | **161** | **191** | **352** |
| | | Percentage | 100.00 | 100.00 | 100.00 |
| 4 | < 18 years | | 70 | 125 | 195 |
| **Total** | | Number | **231** | **316** | **547** |

Source: DPR SIA 2020, DMRCL

## (2) Economic Status and Occupational Pattern

### Number of Working Persons

The economic status has been assessed and it is found that there are 178 workers among PAPs. Thus, 32.54% are economically active persons among PAPs and 67.46 % are non-working PAPs.

On an average there are two dependents per earner among PAPs. Or, one household has average 1.6 working persons (178/111=1.60)

In Corridor-1, there are 74 workers and 157 non workers, while in Corridor-2, there are 104 workers and 212 non workers. Thus, the distribution of worker and dependents is almost similar in both corridors.

### Occupation

The occupation and profession of the economically active person has been considered during the social survey. The study recorded and assessed the capability, base for livelihood and skills of the family head, so that resettlement impacts can be assessed. Based on the impacts assessment, the income generation plan and rehabilitation plans shall be prepared accordingly. The occupation pattern of PAPs is given in the table below.

The survey data show that 64.61% persons are engaged in business activities, 28.09% are working in hired jobs and another 7.30 % are engaged in other activities. There are two doctors and three people have only rental income.

**Table 15-63: Occupation-wise Distribution of PAPs**

| S.No. | Occupation | No. / % | Corridor- 1 | Corridor-2 | Total |
|---|---|---|---|---|---|
| 1 | Job | Number | 10 | 40 | 50 |
| | | Percentage | 13.51 | 38.46 | 28.09 |
| 2 | Business | Number | 59 | 56 | 115 |
| | | Percentage | 79.73 | 53.85 | 64.61 |
| 3 | Others | Number | 5 | 8 | 13 |
| | | Percentage | 6.76 | 7.69 | 7.30 |
| **Total** | | Number | **74** | **104** | **178** |
| | | Percentage | **100.00** | **100.00** | **100.00** |

Source: DPR SIA 2020, DMRCL

### (3) Monthly Income of PAPs

The distribution of income among the working PAPs is given in the table below.

The survey result clearly shows that there are 40.45 % PAPs who earn less than INR. 10,000/- per month. Another 24.72% earn between INR.10,000/- to INR. 20,000/- per month. Thus, the monthly income of about two third earning PAPs is less than INR. 20,000/per month.

About 20 % PAPs are earning between INR. 20,000/- to 50000/- per month and 14.61 % are earning between INR.50,000/- to INR. 100,000/- per month and another 5.06% are earning more than INR. 100,000. per month.

Out of the total surveyed households (111), 7 households are found earning below poverty line – one in Corridor-1 and 6 in Corridor-2. It means about 94% households are in APL category and 6% are in BPL category among the surveyed households.

Household Poverty Line in Bihar is estimated between INR. 4,500 and INR. 6,200 per household per month in Table 15-12.

**Table 15-64: Distribution of Monthly Personal Income of Working PAPs**

| S.No. | Monthly Household Income | No/ % | Corridor-1 | Corridor- 2 | Total |
|---|---|---|---|---|---|
| 1 | Less than INR.10,000/- | Number | 8 | 64 | 72 |
| | | *Percentage* | *10.81* | *61.54* | *40.45* |
| 2 | INR.. 10,000/- - INR.. 20,000/- | Number | 21 | 23 | 44 |
| | | *Percentage* | *28.38* | *22.12* | *24.72* |
| 3 | INR..20,000/- to INR.. 50,000/- | Number | 26 | 10 | 36 |
| | | *Percentage* | *35.14* | *9.62* | *20.22* |
| 4 | INR..50,000/- to INR.100,000/- | Number | 10 | 7 | 17 |
| | | *Percentage* | *13.51* | *6.73* | *9.55* |
| 5 | More than INR.. 100,000/- | Number | 9 | 0 | 9 |
| | | *Percentage* | *12.16* | *0* | *5.06* |
| | **Total** | Number | **74** | **104** | **178** |
| | | *Percentage* | **100.00** | **100.00** | **100.00** |

Source: DPR SIA 2020, DMRCL

### (4) Assets of Families

Data collected from the survey revealed that most of the PAHs belong to the middle class.

Being in Patna city most of them have access to cooking gas, sanitation and hygiene facilities. It is found that 53 households have separate kitchen in their house and 61 households have toilets in their houses.

So far as fuel used in kitchen, 81% PAHs use LPG, and balance 19 % use wood for cooking their food on Chulha (cooking stove).

Source of water supply is piped supply for 89.19% PAHs, out of which about 37% PAHs have supplemented this with domestic tube well. Only about 11 % PAHs are dependent on water supply using hand pump.

Most of the PAHs have Fans (98%), Radio (21.62%) and TV (57.66%). About 32.43% PAHs also own Washing machines and 39.64 % own Refrigerators.

In terms of vehicles, 45% of PAHs own two-wheelers and 19.8% PAHs also own four-wheelers.

### (5) Vulnerable Families

Of the 111 PAHs surveyed, a total of 28 households that are considered to be socially vulnerable and susceptible to negative effects were found as shown in the following table. Of these, 22 households in total belong to the Scheduled Caste. There were 6 households with incomes below the poverty line, 6 households headed by women, and 1 household including persons with disabilities. Notably, all PAHs, except 1 at Raza Bazar, are squatters or commercial encroachers located on public land.

**Table 15-65: Vulnerable Families**

| Sr No. | Type of Vulnerable Family | Number, Location | Total in DPR, Eligible for Compensation | Update July 2022 on Site |
|---|---|---|---|---|
| 1 | Disability – Blind | 1 Malahi Pakri (squatter) | 1 | 0 |
| 2 | Scheduled Castes with Below Poverty Line | 4 Malahi Pakri (squatters) | 4 | 0 |
| 3 | Scheduled Castes with Women Headed Family | 3 Malahi Pakri(squatters) | 3 | 0 |
| 4 | Scheduled Castes | 1 Khemni Chak,<br>14 Malahi Pakri (squatters) | 15 | 1 |
| 5 | Below Poverty Line Families | 1 Bhootnath to Zero Mile,<br>1 Zero Mile (all commercial encroachers) | 2 | 2 |
| 6 | Women Headed Families | 1 Raza Bazar,<br>2 Malahi Pakri (squatters) | 3 | 1 |
| | **Total** | | **28** | **4 (24 to be tracked)** |

Source: DPR SIA 2020, DMRCL, p. 48, Annexure 3

### (6) Awareness about HIV/AIDS

Sex trade and the spread of sexually transmitted diseases (STDs) also comes up as critical socio-cultural and health issue, which needs to be addressed to ensure that the construction of the Metro rail project is a socially responsible development project.

Most of the respondents have shown awareness about HIV/ AIDS. The main source of information is television, newspaper and advertisement boards displayed by the government in the city.

Taking into consideration the safety issues of risks of HIV/ AIDS during the project construction period, proper training shall be imparted to labours by the contractor team engaged for the construction work. It is presumed that labour working in the project may not be aware of the hazards of the disease.

### (7) Awareness and Opinion About the Project

During the socio-economic survey, some questions were asked from the PAPs regarding the awareness, source of information and opinion about the proposed Metro project.

It is reported by 83% in Corridor1 and 76% in Corridor2 and overall, 79% interviewee answered that they were aware of the Project before the visit of this team. The source of information ranged from Newspaper, Radio/ TV and the word of mouth as several teams have visited the area to perform preparatory works for the Project.

Moreover, 74% of Corridor1 and 96% of Corridor2 and overall, 87% of them categorized the Project as good in general terms.

### (8) Resettlement & Rehabilitation Options

The options on resettlement and rehabilitation measures have also been collected from Project Affected Households. Different people have opted for different type of compensation acceptable to them.

Some have asked to provide jobs to the family members in the organization. Another set of PAHs asked to provide them compensation as per new Land Acquisition Act on market rate which is higher than the Circle rates. Many people have asked to provide them training for skill development.

### (9) Common Property Resources/Public Utilities

The common property resources are getting affected due to construction of the proposed Project. Five Temples and three public toilets are getting affected. The common property resources and structures related to public utilities should be suitably shifted, rehabilitated, and or compensated in accordance with the consent of local communities.

## 15.7 Eligibility and Entitlements for Compensation, Rehabilitation, and Resettlement

### 15.7.1 Eligible PAHs/PAPs

PAHs/PAPs entitled to compensation and rehabilitation are listed below.
Based on the JICA Guidelines, all who were recognized as PAHs/PAPs during the date of the Census Survey for DPR SIA, which is May 2020, are eligible, no matter the length of their tenancy more than or less than 3 years. As of September 2022, PMRCL is awaiting its Board decision to make those who have tenancy of less than 3 years as eligible PAHs/PAPs.

(i) PAHs/PAPs with legal title or traditional land rights losing land and assets attached to the land will be compensated for the loss, and will receive assistance for rehabilitation and relocation.
(ii) Non-title holder PAHs/PAPs losing residences and commercial assets to on public land as well as on private land will be compensated for the loss, and will receive assistance for rehabilitation and relocation.
(iii) Commercial tenant and lessees PAHs/PAPs losing immovable assets and their investment will be compensated for the loss, and will receive assistance for rehabilitation and relocation.
(iv) PAPs losing business, income, and salaries will be compensated for the loss.
(v) PAHs/PAPs who belongs to the Vulnerable Groups will receive additional assistance.

### 15.7.2 Cut-Off Dates

The final cut-off date for those who have legal title is the date of Article 11 Notification based on the Land Acquisition Act 2013.

The preliminary cut-off date for those who have legal title, and the final cut-off date for non-title holder PAHs/PAPs is the date of the Census Survey for DPR SIA, which is May 2020.

In the letter issued on September 21, 2022, PMRCL agreed that 1) the PAHs related to the structures that have already moved out from the locations listed in DPR SIA 2020 will be contacted, and 2) the payment of the compensations, relocations and rehabilitations for the PAHs will be started.

### 15.7.3 Entitlement Matrix

#### (1) Entitlement Matrix

The following table presents the entitlement matrix for the Project.

The Entitlement was updated on the point of the range of PAHs who will receive the relocation and rehabilitation assistances. The DPR SIA was giving those relocation and rehabilitation assistances to PAHs fully and partially affected PAHs (including commercial owners and tenants). JST studied the land acquisition plan drawings, and concluded that the impacts on partially affected PAHs are limited to losing part of their front parking spaces. Their main structures will not be affected, they will not need to resettle or relocate, and their means of livelihood are not to be affected. Therefore, the partially affected PAHs are eligible for compensation for the loss of their land and asset (i.e. boundary walls and parking roof), but not eligible for the relocation and rehabilitation assistances. Therefore, the 16 PAHs who will be partially affected were excluded from the entitled PAH from the Rehabilitation entitlements.

Detailed entitlements of livelihood rehabilitation activities, including responsible implementation agencies, role of PMRCL, necessary budget, reporting requirements, are explained in Attachment 17.

**Table 15-66: Entitlement Matrix**

| Entitlement Matrix (Compensation for land acquisition) | | | |
|---|---|---|---|
| **S.No** | **Category of Impact** | **Eligibility for Entitlement** | **PMRCL Adopted Policy/Entitlement** |
| 1. | Loss of Private Land | Title holder | Market value/ Circle rate as per stamp Act.<br>(The First Schedule of the Act 2013 i.e. "Serial No. 1"). |
| 2. | Loss of other immovable assets (value of assets attached to land or building) | Titleholder<br>Tenants investing in rental unit | Will be determined on the basis of valuation by authorized expert based on a replacementvalue.<br>(The First Schedule of the Act 2013 i.e. "Serial No. 4"). |
| 3. | Solatium for loss of Land, Structure and other immovable assets | Titleholder | 100% of arrived value of land and building. The compensation is calculated for land, structures and such assets attached to the building or land as applicable and the total of all considered before considering the solatium, including any transaction costs and fees.<br>(The First Schedule of the Act 2013 i.e. "Serial No. 5"). |
| 4. | Loss of otherimmovable assets (value of assets attached to land or building) | Squatters/ Encroachers | One-time financial assistance based on valuation of the property subject to a minimum of **Rs.25,000.**<br>(No Provisions in Act but similar to Item No. 7 of Second Schedule of Act 2013 ) |

| Entitlement Matrix (Rehabilitation) | | | |
|---|---|---|---|
| **S.No** | **Category of Impact** | **Eligibility for Entitlement** | **PMRCL Adopted Policy/Entitlement** |
| 5. | Constructionallowance | Displaced family whose residential structure is lost dueto acquisition | **Rs. 1, 50,000** will be given to displaced family whosedwelling units are lost completely or become unviable due to displacement. The amount has been worked out on the basis of construction of house as per Indira Awas Yojana of GOI.<br>(Item No. 1 of Second Schedule of Act 2013 i.e. Provision of housing units in case of displacement from private Land ) |
| 6 | Subsistence grant for displaced family | Displaced family (including tenants/leaseholders, residential squatters and encroachers) | Onetime payment of **Rs.36,000** shall be paid to each Displaced Family.Displaced Family belongingto the Scheduled Castes or the Scheduled Tribes orvulnerable group (including households headed by Females/ Physically Challenged persons/ Senior Citizens without having adult members) shall receive an amount equivalent to fifty thousand rupees. (**Rs.50,000**). This amount is additional to subsistence grant.<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 5"). |
| 7. | Transportation cost | Displaced family (including tenants/leaseholders/squatters/encroachers) | One time financial assistance of **Rs.50,000** for shifting family, building material, belongings and cattles shall be given to each displaced family.<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 6"). |
| 8. | Cattle shed / pettyshops including moving carts | Affected Family (including tenants/leaseholders/ squatters/encroachers) | Each Affected Family having cattle shed or having a petty shop in the acquired land shall get one-time financialassistance based on valuation of the structure subject to a minimum of **Rs. 25,000** for re-construction of cattle shed or petty shop as the case may be.<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 7"). |
| 9. | One time grant to artisan, small tradersand certain others | Affected Family (including tenants/leaseholders, commercial squatters and encroachers) | Each Affected Family of an artisan, small trader or self-employed person (including workers/wage earners working in non-titleholder commercial establishments like mobile vendors/kiosks) or a Displaced Family which owned non- agricultural land or commercial, industrial or institutional structure in the affected area, shall get one-time financial assistance based on valuation subject to minimum of **Rs. 25,000**. In case |

| Entitlement Matrix (Rehabilitation) | | | |
|---|---|---|---|
| | | | of temporary displacement of affected persons, allowance for their wage loss for a fixed number of days may be given at applicable state government rates for unskilled labour.<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 8"). |
| 10. | One time resettlement allowance | Affected Family (including tenants/leaseholders, squatters, encroachers.<br>Not in Act. Similar to S.N. 4 of above | Each Affected Family will be given a one time resettlement allowance of<br>**Rs. 50,000.**<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 10"). |
| 11. | Loss of Livelihood | Affected family (including Tenants/ Lease holders, Employees)<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 4" excluding Employee ). | The head of the household of all affected families livelihood due to land acquisition will be provided with one-time payment of with **Rs. 5,00,000** (per affected family)<br>(The Second Schedule of the Act 2013 i.e. "Serial No. 4" excluding Employee ). |
| 12. | Job training for vulnerable groups | Commercial and Residential Squatters/ Encroachers belonging to vulnerable groups. | Vulnerable groups shall be given job training in addition to other entitlements, if opted for by the PAPs. Resettlement and Rehabilitation Committee will refer PAPs to existing job training schemes offered by welfare schemes already provided in the State of Bihar.<br>(Not covered in Act/Rules but proposed to be covered with help of provisions of various welfare schemes of Govt of Bihar). in reference to fourth point of Item No. 2.1 of draft RPF. |
| 13. | Commercial and Residential Squatters | Additional livelihood restoration measures | Each family shall be given assistance by PMRCL or an NGO appointed by PMRCL to appraise them for applying to existing public welfare schemes already provided in the State of Bihar.<br>(Not covered in Act/Rules but proposed to be covered with help of provisions of various welfare schemes of Govt of Bihar). in reference to fourth point of Item No. 2.1 of draft RPF. |

Source: JST, PMRCL, December, 2022

### (2) Additional Assistances for the Vulnerable Groups

As shown in Table 15-65, most of the PAHs who belong to the Vulnerable Groups are also informal settlers who are eligible for additional assistances listed in Line 14 of Table15-66, Entitlement Matrix. Such additional assistances include access to business loans and priority in job recruitment. Therefore, training programs of personal bank account management and business loan management will be given by the bank to the PAHs who opt for those assistances. For those who opt for priority jobs, on-the-job training opportunity will be available according to each person's capabilities and aptitude at their workplaces.

### (3) Tenants and Employees with Tenancy/Contract Less Than 3 Years at the Cut-Off Date

JST is under process to confirm the policy of PRCL based on the 2013 Land Acquisition Act about the tenants and employees with tenancy/contract less than 3 years at the Cut-Off Date.

The question is that 'if a PAH/PAP shown as No.3 to No.7 in Table 15-55 has tenancy or contract less than 3 years, will he/she be eligible for the compensation entitlement listed in Table 15-66 No.5 to No.13, just the same as those who has tenancy or contract not less than 3 years?'

JST is planning a discussion on this matter in November 2022.

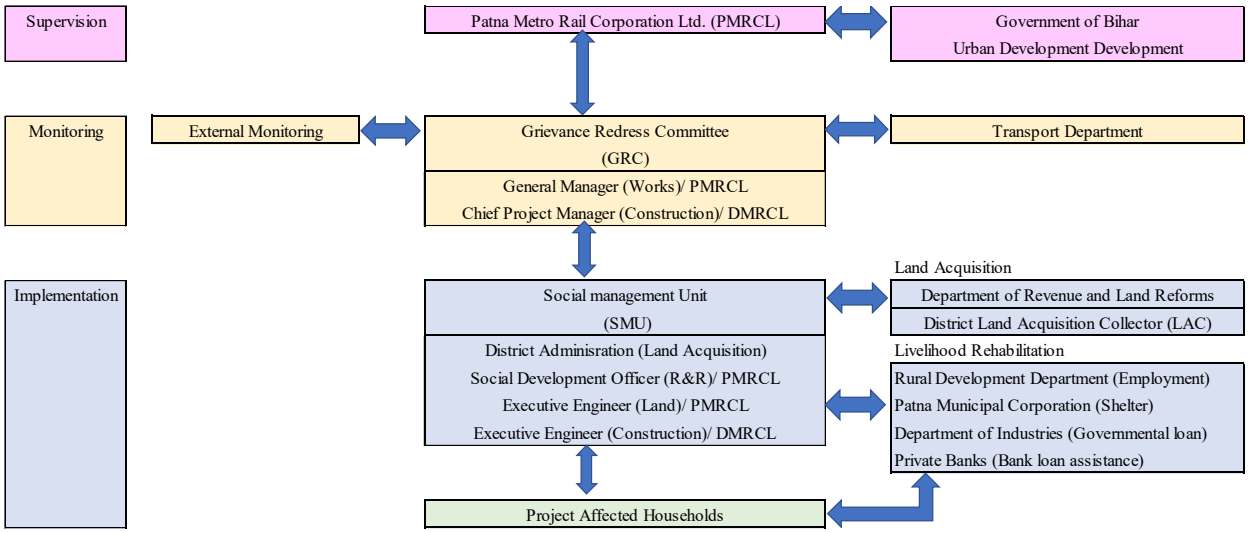
According to the JICA Guideline, not only the squatters or encroachers, but those tenants and employees identified on the Cut-Off Date must be eligible without regard of their length of the tenancy or contract.

## 15.8 Institutional Arrangement

The implementation of Resettlement Action Plan (RAP) requires involvement of various institutions at different stages of project cycle. This section deals with roles and responsibilities of various institutions for a successful implementation of the RAP. The institutions to be involved in the process are as follows:

1. Patna Metro Rail Corporation Ltd. (PMRCL)
2. Delhi Metro Rail Corporation Ltd. (DMRCL)
3. Office of the District Collector in Patna.

The institutional framework for RAP implementation is shown below. PMRCL will take responsibility at every level of implementation, which are supervision, monitoring, and implementation. DMRCL, as the design-build project consultant and contractor, will assist in monitoring and implementation by taking member seats in the Grievance Redress Committee and the Social Management Unit. Social Management Unit takes the role of RAP implementation, working together with the District Administration. Most of the works that need direct communication with the PAHs will be handled by the office of District Administration. As of September 2022, PMRCL hired an internal specialist for Resettlement and Rehabilitation, but an outside consultant for evaluation has not yet been contracted.




Source: JST based on DPR SIA 2020

**Figure 15-3: Institutional Arrangement of Implementation of Land Acquisition and Livelihood Rehabilitation**

### 15.8.1 PMRCL/ DMRCL

Patna Metro Rail Corporation Ltd. will be the Project executing and implementing agency for the proposed metro rail project in Patna. PMRCL will be overall in charge of rehabilitation and resettlement issues such as implementation, monitoring and execution of land acquisition and resettlement issues. The designated engineering department headed by Chief Project Manager in PMRCL will assess the requirement of land acquisition and resettlement based on the engineering design.

PMRCL will be responsible for coordinating with other concerned government departments for land acquisition, planning and implementation of RAP which will include the disbursement of compensation, assistance, shifting and relocation of affected people. PMRCL will also arrange/ provide vocational training and other welfare assistance to the affected people.

To ensure proper coordination and execution of the land acquisition and resettlement issues and to ensure coordination with the implementing agency, an independent evaluation consultant (Resettlement & Rehabilitation) may be hired by PMRCL for mid and end term evaluation of implementation of resettlement and rehabilitation activities.

The independent evaluation consultant may review RAP implementation in light of the objectives, targets, budget and duration that is laid down in the plan.

PMRCL will report to JICA 4 times a year (quarterly) regarding the progress made on land acquisition and implementation of resettlement plan.

Above PMRCL tasks will be assisted by DMRCL, as the design-build project consultant and contractor procured on September 2019.

### 15.8.2 Department of Revenue and Land Reforms

Department of Revenue and Land Reforms, Government of Bihar is responsible for large-scale acquisition of land for planned development. Land Acquisition Branch of the Department is responsible for overall coordination between various agencies involved in land acquisition.

For acquisition of private land for the proposed project, PMRCL will place requisition of land to Transport Department, who in turn will forward the requisition to the Department. On receipt of the proposal for acquisition of land from Transport Department, the Land Acquisition Branch of the Department will forward the same to the District Land Acquisition Collector (LAC) to initiate the process for acquisition of land. Land will be acquired by LAC/ the Department under "The Right to Fair Compensation and Transparency in Land Acquisition, Rehabilitation and Resettlement Act, 2013 (No. 30 OF 2013)" and Bihar Government Rules (2014).

### 15.8.3 Office of the District Land Acquisition Collector

The proposed project covers Patna city of Bihar. The Patna District has a Land Acquisition Collector (LAC). The office of the LAC will be responsible for the land acquisition. District Land Acquisition Collector will coordinate between the PMRCL and the affected landowners. PMRCL will provide technical details and the land acquisition plans, as well as the funding for land acquisition, rehabilitation and resettlement, to the LAC.

The LAC will be responsible for initiating and issuing notice under the Land Acquisition Act 2013 and the LAC will be responsible for conducting the valuation of affected land and assets, will decide and disburse the compensation and assistances.

### 15.8.4 Social Management Unit (SMU)

PMRCL will have a division thai shall be looking after the social safeguards activities. This is headed by

the Deputy Chief Engineer (Land) who coordinates with other divisions/ sections of PMRCL on social, rehabilitation and resettlement issues. Other members of this unit will include the concerned Deputy Chief Engineer of the line/ corridor referred to as Deputy Chief Engineer (construction), Executive Engineer (land) and Executive engineer of the concerned line/ corridor. PMRCL will do the overall coordination, preparation, planning, implementation, and financing of RAP.

The Social Management Unit (SMU) of PMRCL will work closely with other staff of the PMRCL and will be specifically looking after the social safeguards issues. The SMU shall ensure that all land acquisition issues are handled according to the LA policy/ guidelines as it is laid down in this report. It will also monitor that all the procedural and legal issues involved in land acquisition are fulfilled. The SMU will work for getting all the necessary clearances and implementation of the resettlement activities prior to start of any civil work. A Social Development Officer (R&R) with background of social science may be added in this SMU as full time to supervise and monitor overall activities of RAP and he/ she will report day to day progress to Deputy Chief Engineer (Land).

Some of the specific functions of the SMU in regards to resettlement management will include the following:

- Take Overall responsibility of planning, implementation and monitoring of land acquisition and resettlement and rehabilitation activities in the Project;
- Ensure availability of budget for R&R activities;
- Coordinate stakeholder agencies (District Administration (Land Acquisition Collector (LAC)), Patna Metro Corporation), the Land Acquisition Branch of the Transport Department, and the assistance provider agencies for trainings), support for land acquisition, and implementation of land acquisition, resettlement, and rehabilitation.
- Coordinate with line Departments, such as National Highway Authority, Indian Rail, and other landowner departments.
- Monitor progress and due-diligence of land acquisition and R&R activities
- Procure the external monitoring of land acquisition and R&R activities

As of September 2022, PMRCL has staffed 4 out of 5 necessary personnel for SMU as shown in the table below. Until the official establishment of the SMU, the Director (Project), is taking lead in communication and coordination between the Patna District Administration and the Social Development Officer in PMRCL. Based on the communication, the Director (Project) gives necessary instructions to the Engineers responsible for land (PMRCL) and construction (DMRCL).

In the letter dated September 21, 2022, PMRCL expressed that the Resettlement and Rehabilitation Policy for the Project is likely to be approved by the State Government by October 10 2022. The establishment of the SMU may follow soon after the approval of the Policy.

**Table 15-67: Institutions for Resettlement Activities**

| Institution | Planned Member (DPR SIA 2020) | Agreed Staffing 2022 |
|---|---|---|
| Social Management Unit (SMU) | Deputy Chief Engineer (Land) | Patna District Administration |
| | Deputy Chief Engineer (Construction) | To be named |
| | Social Development Officer (Rehabilitation and Resettlement) | Staffed in PMRCL |
| | Executive Engineer (Land) | Staffed in PMRCL |
| | Executive Engineer (Construction) | Staffed in DMRCL |
| Grievance Redressal Committee (GRC) | Chief Engineer (General) | Director (Projects), PMRCL |
| | Chief Project Manager (Construction) | Designated officers from Revenue Department and Social Welfare Department of District Administration and the Government of Bihar |

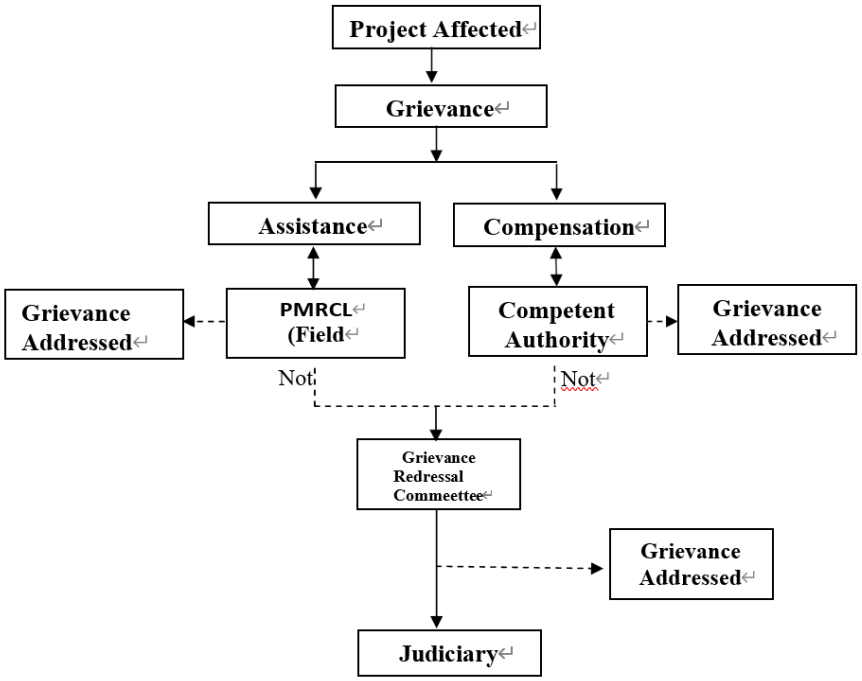
Source: JST, based on DPR SIA 2020 and PMRCL

### 15.8.5 Grievance Redressal Committee

Grievances of PAPs will be first brought to the attention of field level officer. If Grievances are not redressed at Field Level it will be brought to the Grievance Redressal Committee (GRC). GRC will review grievances involving all resettlement benefits. However, other disputes relating to ownership rights shall be considered by the court of law.

When any grievance is brought to the field level, it should be resolved within 45 days from the date of complaint. The GRC will meet every month (if grievances are brought to the Committee), determine the merit of each grievance, and resolve grievances within three months of receiving the complaint failing which the grievance can be referred to appropriate court of Law for Redressal by the PAP.

PMRCL will maintain a log of grievances documenting the nature of grievance, date of submission, responsible party and date of resolution.




Source: PMRCL

**Figure 15-4: Stages of Grievance Redressal Process**

## 15.9 Implementation Schedule

### 15.9.1 Project Preparatory Stage (Pre- Implementation Stage)

Setting up relevant institutions for the resettlement activities will be the major task during the preparatory stage which is pre-implementation phase. The major activities to be performed in this period include the establishment of Social Management Unit (SMU) and additionally, the Grievance Redressal Committee (GRC) needs to be appointed at this stage.

As of September 2022, required members of those institutions are already assigned inside or outside of PMRCL. Setting up of SMU and GRC is not started yet.

**Table 15-68: Institutions for Resettlement Activities**

| Institution | Planned Member (DPR SIA 2020) | Staffing |
|---|---|---|
| Social Management Unit (SMU) | Deputy Chief Engineer (Land) | Patna District Administration |
| | Deputy Chief Engineer (Construction) | To be named |
| | Social Development Officer (Rehabilitation and Resettlement) | Staffed in PMRCL |
| | Executive Engineer (Land) | Staffed in PMRCL |
| | Executive Engineer (Construction) | Staffed in DMRCL |
| Grievance Redress Committee (GRC) | Chief Engineer (General) | General Manager (Works), PMRCL |
| | Chief Project Manager (Construction) | Staffed in DMRCL |

Source: JST, based on DPR SIA 2020 and PMRCL

### 15.9.2 Land Acquisition Implementation Stage

According to the 2013 Land Acquisition Act, State Scheme for Rehabilitation and Resettlement will be prepared by the District Administration using the PMRCL policies and the entitlement defined in the Act as the basis, and will be disclosed to the PAPs. Upon the approval of the State Scheme, all the arrangements for fixing the compensation and the disbursement needs to be done which includes payment of all eligible assistance; relocation of PAPs; initiation of economic rehabilitation measures.

The resettlement and rehabilitation fund will be monitored as part of the scheme implementation at this stage. Internal monitoring will be the responsibility of PMRCL which will start in early stage of the project when implementation starts and will continue till the completion of the implementation of land acquisition, resettlement and rehabilitation. PMRCL will be responsible for carrying out the monitoring on quarterly basis, and the quarterly report will be submitted to JICA for review.

### 15.9.3 Monitoring and evaluation phase

Public consultation, internal monitoring and grievance redressal will be undertaken intermittently throughout the project duration. Livelihood rehabilitation monitoring for those who received rehabilitation assistances is required for 3 years after the completion of payment of compensation, resettlement, and rehabilitation. The monitoring schedule is subject to modification depending on the progress of the project activities.

Activities in the monitoring and evaluation phase are described in detail in Section 15.10.

### 15.9.4 RAP Implementation Schedule

Public land acquisition process is on-going on the basis of individual negotiation with the owner institutions. Where the target land is transferred to PMRCL, civil works has begun. The PAHs who were residing or operating commercial business on those public land moved out without receiving compensation or assistance. PMRCL, in a letter dated September 21, 2022, promised that those PAHs will be contacted, and the payment will be started by the District Administration.

For the private land title holders, District Administration, on behalf of State of Bihar, is implementing the land acquisition process following the instruction of the Land Acquisition Act 2013. The 11 locations (10 stations and Depot) that need private land are grouped into 6 units, and the process is handled by the units.

Regarding current progress, it is assumed that payment of compensation and taking of land will take time into the middle of 2023.

PMRCL needs to set up the Social Management Unit, and the Grievance Redress Committee, and to start quarterly reporting to JICA by the end of December 2022. PMRCL also need to procure external evaluation expert for mid-term and end-term monitoring of RAP implementation. Sample TOR for the external evaluation expert is shown in Attachment 18.

## Table 15-69: RAP Implementation Progress and Schedule

| | | 2020 | | | | 2021 | | | | 2022 | | | | 2023 | | | | 2024 | | | | 2025 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 | 1 | 2 | 3 | 4 |
| 1. | Commencement of Operation | | | | | | | | | | | | | | | | | | | | | | | | |
| 2. | Preliminary Identification of Required Land (DPR) | | | | | | | | | | | | | | | | | | | | | | | | |
| 3. | Preliminary Identification of PAHs (DPR SIA) (Cut-off date for informal settlers) | | | | | | | | | | | | | | | | | | | | | | | | |
| 4. | Community/ Public Consultation (DPR) | | | | | | | | | | | | | | | | | | | | | | | | |
| 5. | DPR approval by State of Bihar | | | | | | | | | | | | | | | | | | | | | | | | |
| 6. | Negotiation and transfer of public land | | | | | | | | | | | | | | | | | | | | | | | | |
| 7. | State SIA survey to assess the impact | | | | | | | | | | | | | | | | | | | | | | | | |
| 8. | Public hearing (on State SIA) | | | | | | | | | | | | | | | | | | | | | | | | |
| 9. | Identification of Required Land (Art. 11 Notification)(Cut-off date for title holders) | | | | | | | | a | b | | | | | | | | | | | | | | | |
| 10. | State Census of PAHs, including identification of all title holders | | | | | | | | | | | | | | | | | | | | | | | | |
| 11. | Boundary, topo, and boring survey on site | | | | | | | | | | | | | | | | | | | | | | | | |
| 12. | Valuation of land, structures, and other assets | | | | | | | | | | | | | | | | | | | | | | | | |
| 13. | Declaration of land to be acquired (Art. 19 Notification) | | | | | | | | | | c | | | | | | | | | | | | | | |
| 14. | Payment for compensation, relocation and rehabilitation by District Administration | | | | | | | | | | | | | | | | | | | | | | | | |
| 15. | Taking of land by PMRCL | | | | | | | | | | | | | | | | | | | | | | | | |
| 16. | State Approval of Patna Metro Resettlement Policy Framework | | | | | | | | | | | | | | | | | | | | | | | | |
| 17. | PMRCL Set up of Social Management Unit and Grievance Redress Committee | | | | | | | | | | | | V | V | V | W | W | W | W | W | W | W | W | W | W |
| 18. | PMRCL Internal monitoring (including post- resettlement monthly monitoring for 2 years) | | | | | | | | | | | | V | V | V | W | W | W | W | W | W | W | W | W | W |
| 19. | PMRCL Quarterly report submission to JICA | | | | | | | | | | | | V | V | V | | X | | X | | X | | X | | |
| 20. | PMRCL Procurement of External Evaluation Specialist | | | | | | | | | | | | | | | | | | | | | | | | |
| 21. | External evaluation (mid term and end term + 2 years) | | | | | | | | | | | | | | | Y | | | Z | | | | Z | | |

a. Depot, b. New ISBT Sta., c. Depot and.New ISBT Sta.

V: Monthly monitoring and quarterly reporting of progress of land acquisition, payment of compensation, and grievance redress will continue until the actual completion of the payment of compensation and rehabilitation..

W: Monthly monitoring of grievances and complaints for 2 years after the actual completion of the payment of compensation and rehabilitation.

X: Biannual reporting to JICA will start after the actual completion of the payment of compensation and rehabilitation.

Y: End term evaluation will be implemented after the actual completion of the payment of compensation and rehabilitation.

Z: 2 annual monitoring of RAP achievements after the actual completion of the payment of compensation and rehabilitation..

Source: JST, PMRCL

## 15.10 Cost and Budget

### 15.10.1 Cost Estimate and Budget

The cost of land and structure, including 100 % solatium and 12 % interest rate, is calculated as INR. 2,880.36 Crore (INR. 28,803.6 million) as per July, 2022. It was confirmed that the estimated cost for land and structure is within the budget secured based on the DPR 2021, which is INR. 2,881.83 Crore (INR. 28,818.3 million).

**Table 15-70: Details of Cost of Land and Structure**

| S. No. | Description | Entitlement | Unit | *QTY (DPR)* | QTY (2022) |
|---|---|---|---|---|---|
| 1 | Cost of permanent Land Acquisition including 100 % Solatium and interest thereon @ 12% | Replacement Cost | ha | *97.355* | 47.625* |
| 2 | Acquisition of structures | | | | |
| 2.1 | Residential Houses (title holder) | Compensation for residential structure | Per Unit | *7* | 5 |
| 2.2 | Commercial structure (title holder) | Compensation for Commercial structure | Per unit | *42* | 23 |
| 2.3 | Commercial tenant (Full: 28, Partial 7) | Compensation for investment | Per unit | - | 35 |
| 2.3 | Residential + Commercial | Compensation for structure | Per Unit | *4* | 3 |
| 2.4 | Institutional Structure | Compensation for structure | Per Unit | *1* | 1 |
| 2.5 | Squatters (40), commercial encroachers (8) | Compensation for structure | Per unit | *45* | 48 |
| | **Budget (Land + Structure)** | | **INR. Crore** | **2,881.83** | |
| | **Cost Estimate as of July 2022** | | **INR. Crore** | | **2,880.36** |

*: See Table 15-28, Line 4.
Final valuation of land and/ or structure to be done by Govt. Approved Valuer/ PWD
INR. 1 Crore = INR. 10 million.

Source: Land, Cost Estimate: Data received from PMRCL on August 29, 2022. 'Land details as per July, 2022'
Quantity of eligible structures (2022): JST
Budget: DPR

The estimated cost for resettlement and rehabilitation (R&R) in DPR SIA 2020 was INR. 5.8219 Crore (INR. 58.219 million.). The updated Project cost estimation provided by PMRCL on 9 September 2022 expect INR. 11.65 Crore (INR. 116.5 million) as the budget for R&R.

The detail of R&R budget based on the updated number of target PAHs is given in the table below. By eliminating partially affected PAHs from payment of shifting, resettlement, and subsistence allowances, as well as from annuity payment, the total cost for resettlement and rehabilitation is estimated as INR. 3.228 Crore (INR. 32.28 million.), which is within the prepared budget of INR. 11.65 Crore (INR. 116.5 million).

**Table 15-71: Details of Cost of Resettlement and Rehabilitation**

| S. No. | Description | Entitlement | Unit | *QTY (DPR)* | QTY (2022) | Rate INR. Lakh | Amount INR. Lakh |
|---|---|---|---|---|---|---|---|
| 1. | Shifting of Kiosk (3) and Milk parlor (7) | One-time artisan grant (inconvenience fee) | No. | *3* | 10 | 0.25 | 2.50 |
| 2. | Shifting Allowance (Residential and Commercial) | A lump sum shifting allowance of INR.50,000/- | No. | *134* | 101 | 0.50 | 50.50 |
| 3. | Resettlement Allowance (Residential) | A lump sum Resettlement allowance of INR.50,000/- | No | *134* | 48 | 0.50 | 24.00 |
| 4. | Subsistence Allowance (Residential) | For a period of one year @INR.3000/ month (36,000/year) | No. | *134* | 46 | 0.36 | 16.60 |
| 5. | Choice of Annuity or Employment (Commercial) | A lump sum compensation @ INR. 500,000. | No. | *69* | 35 | 5.0 | 175.00 |
| 6. | Vulnerable Families | Training etc. | No. | *28* | 28 | 0.15 | 4.20 |
| 7. | Community structures (temples, public toilets etc.) | Compensation for structure | Lump sum | - | - | - | 30.00 |
| 8. | Independent Evaluation | | Lump sum | | | | 10.00 |
| 9. | Miscellaneous | | Lump sum | | | | 10.00 |
| 10. | **Cost Estimate as of Sep. 2022*** | | | | | | 322.8 (3.228 Crore)* |
| 11. | *Budget (DPR 2021)*** | | | | | | *1165 (11.65 Crore)* |
| 12. | *Total (SIA 2020)**** | | | | | | *582.19 (5.8219 Crore)* |

INR. 1 Crore = INR. 10 million = 100 Lakh
INR. 1 Lakh = INR. 100,000. = INR. 0.01 Crore

Source: *: JST, **: DPRp.17-07, 17-10, ***: DPR SIA 2020.p.85

## 15.11 Monitoring and Evaluation

RAP implementation will be monitored both internally and externally. PMRCL will be responsible for internal monitoring through their field level offices and will prepare quarterly reports on the progress of RAP implementation. An Independent Evaluation Consultant may be hired by PMRCL for mid and end term evaluation of RAP implementation.

### 15.11.1 Internal Monitoring

The internal monitoring for RAP implementation will be carried out by PMRCL. The main objectives of internal monitoring are to:

- Measure and report progress against the RAP schedule;
- Verify that agreed entitlements are delivered in full to affected people;
- Identify any problems, issues or cases of hardship resulting from the resettlement process, and to develop appropriate corrective actions, or where problems are systematic refer them to the management team;
- Monitor the effectiveness of the grievance system
- Periodically measure the satisfaction of project-affected people.

Internal monitoring will focus on measuring progress against the schedule of actions defined in the RAP. Activities to be undertaken by the PMRCL will include:

Liaison with the Social Management Unit, construction contractor and project-affected communities to review and report progress against the RAP;

- Verification of land acquisition and compensation entitlements are being delivered in accordance with the RAP;
- Verification of agreed measures to restore or enhance living standards are being implemented;
- Verification of agreed measures to restore or enhance livelihood are being implemented;
- Identification of any problems, issues, or cases of hardship resulting from resettlement process;
- Through household interviews, assess project affected peoples' satisfaction with resettlement outcomes;
- Collection of records of grievances, follow up that appropriate corrective actions have been undertaken and that outcomes are satisfactory;

Monitoring is a continuous process and will be carried out by Resettlement Specialist on regular basis to keep track of the R&R progress. For this purpose, the indicators suggested have been given in table below.

Field Offices will be responsible for monitoring the day-to-day resettlement activities of the project. Baseline socio-economic census and the land acquisition data provide the necessary benchmark for field level monitoring. A format for monitoring of RAP implementation is presented in Attachment 19.

**Table 15-72: Indicators for Monitoring of RAP Progress**

| Indicators | Parameters Indicators |
|---|---|
| **Physical** | Extent of land acquired |
| | Number of structures dismantled |
| | Number of land users and private structure owners paid compensation |
| | Number of families affected |
| | Number of PAPs receiving assistance/compensation |
| | Number of PAPs provided transport facilities/shifting allowance |
| | Extent of government land identified for house sites |
| **Financial** | Amount of compensation paid for land/structure |
| | Cash grant for shifting PAPs |
| | Amount paid for training and capacity building of staffs |
| | Amount for restoration of CPR (Common Property Resource) |
| **Social** | Area and type of house and facility at resettlement site |
| | Number of time GRC met |
| | Number of appeals placed before grievance redressed cell |
| | Number of grievances referred and addressed by GRC |
| | Number of cases referred and addressed by arbitration |
| | Number of PAPs approached court |
| | Women concern |
| **Economic** | Entitlement of PAPs-land/cash |
| | Number of business re-established |
| | Utilization of compensation |
| | House sites/business sites purchased |
| | Successful implementation of Income Restoration Schemes |

| Indicators | Parameters Indicators |
|---|---|
| **Grievance** | Consultation for grievance redressed |
| | PAPs knowledge about their entitlements |
| | Cases referred to court, pending and settled |
| | Number of grievance cell meetings |
| | Number of cases disposed by SMU to the satisfaction of PAPs. |

Source: DPR SIA 2020

### 15.11.2 Independent Evaluation

As mentioned earlier, an Independent Evaluation Agency (IEA) will be hired by PMRCL for mid and end term evaluation. As of September 2022, PMRCL has hired 1 internal Social Development Officer for rehabilitation and resettlement. External IEA, however, has not yet been assigned.

The list of impact performance indicators suggested to monitor project objectives is delineated in the table below.

**Table 15-73: Indicators for Project Outcome Evaluation**

| | |
|---|---|
| **Objectives** | ➢ The negative impact on persons affected by the project will be minimized.<br>➢ Persons losing assets to the project shall be compensated at replacement cost.<br>➢ The project-affected persons will be assisted in improving or regaining their standard of living.<br>➢ Vulnerable groups will be identified and assisted in improving their standard of living. |
| **Risk Factor** | ➢ Resettlement plan implementation may take longer time than anticipated<br>➢ Institutional arrangement may not function as efficiently as expected<br>➢ NGO may not perform the task as efficiently as expected<br>➢ Unexpected number of grievances<br>➢ Finding a suitable rehabilitation site for displaced population<br>➢ PAHs falling below their existing standard of living |
| **Outcomes and Impacts** | ➢ Satisfaction of landowner with the compensation and assistance paid<br>➢ Type of use of compensation and assistance by landowners<br>➢ Satisfaction of structure owner with compensation and assistance<br>➢ Type of use of compensation and assistance by structure owner<br>➢ % of PAHs adopted the skill acquired through training as only economic activity<br>➢ % of PAHs adopted the skill acquired through training as secondary economic activity<br>➢ % of PAHs reported increase in income due to training<br>➢ % PAHs got trained in the skill of their choice<br>➢ Role of NGO in helping PAHs in selecting trade for skill improvement<br>➢ Use of productive asset provided to PAHs under on time economic rehabilitation grant<br>➢ Type of use of additional assistance money by vulnerable group<br>➢ Types of grievances received<br>➢ No. of grievances forwarded to GRC and time taken to solve the grievances<br>➢ % of PAHs aware about the GRC mechanism<br>➢ % of PAHs aware about the entitlement frame work mechanism<br>➢ PAHs opinion about NGO approach and accessibility |

Source: DPR SIA 2020

### 15.11.3 Reporting Requirements

PMRCL will be responsible for supervision and implementation of the RAP.

PMRCL will prepare quarterly progress reports on resettlement activities and submit the reports to JICA.

The Independent Evaluation Consultant will submit mid and end term evaluation report to PMRCL and determine whether resettlement goals have been achieved, more importantly whether livelihoods and living standards have been restored/ enhanced and suggest suitable recommendations for improvement.

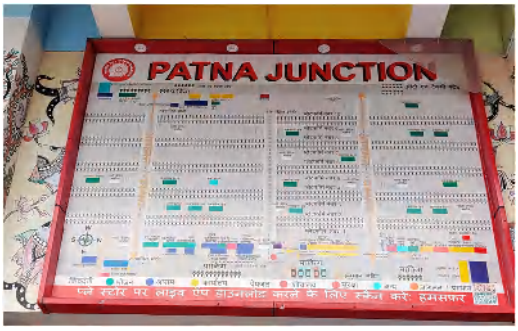
## 15.12 Consideration on Impacts on the Existing Transportation Industry

By opening of Patna Metro, clients of existing public transportation may change their selection of transportation to the new Metro. Therefore, perceptions of the Project by the stakeholders of the existing public transportation was studied.

### 15.12.1 Observation of Existing Urban Transportation in Patna

At present, City Bus Service is operational on more than 10 routes in Patna. There is no uniform and a standard schedule of operation. The daily average number of trips per bus is 14. There are 350 mini-buses. The seating capacity of mini-bus is in the range of 15-20 and fare structure ranges from INR.5 to INR.15. In addition to these, public transport majorly includes shared autorickshaws.

The following photos illustrate the situation in front of Patna Junction Railway Station that observed by JST during the field survey in June 2022. The station plaza (shown as B and C) in front of the station is used for private car parking, where could be used for public transport connections. The roundabout beneath a flyover is used as un-organized bus stops and autorickshaw riding zones, which should be improved.




A. Layout of Patna Junction Railway Station with indications on parking area




B. Unorganized parking and traffic congestions in front of the station



C. Curent station front from another angle



D. Current station front from another angle

Source: JST

**Figure 15-5: Patna Junction Railway Station Front**

In comparison, the Bandra (W) Station in Mumbai is a good example on how regulation of Three-Wheelers and shift of feeder services can change the station front over the years.



In front of the Bandra (W) Station in Mumbai

Uncontrolled situation of autorickshaws and improved operation after 2014 when 3Ws operation was introduced

Nov 2011



May 2014

Source: JST

**Figure 15-6: Mumbai Bandra (W) Station Front**

### 15.12.2 Case Study

JICA has been supporting numerous urban transportation projects. This section explains the strategy taken by the Delhi Metro to organize various mode of transportation by connecting them with the operation of the Metro.

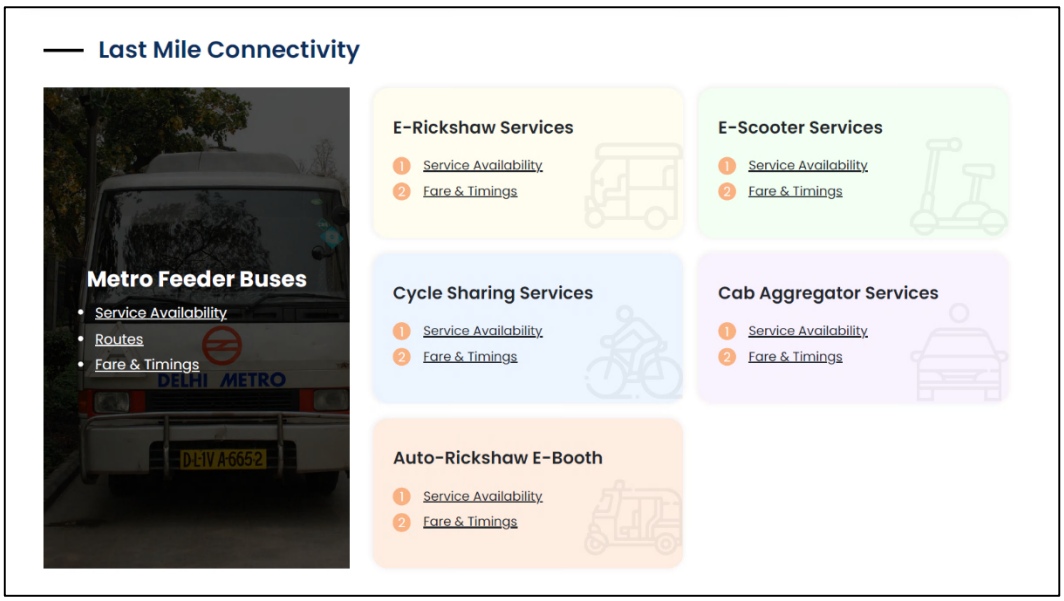
As shown in the table below, Delhi Metro provides Metro users various choices of last-mile transportation. Buses, e-rickshaws, and cabs are available at many Metro stations through the Metro operating hours. For the service providers and drivers of buses, rickshaws and cabs, constant flow of customer can be expected at secured spaces for them.

In addition to above modes, Delhi Metro is operating rental e-scooters and bicycles at their stations. For example, battery operated cycles are available at 41 stations.

**Table 15-74: Last Mile Connectivity Strategy by Delhi Metro**

| | | |
|---|---|---|
| **1** | **Metro Feeder Buses** | Total 47 AC buses are being operated<br>Operating on 05 routes<br>Available at 09 metro station<br>Operating from 06:00AM to 11:00 PM<br>Fares:<br>Up to 04 Kms Rs. 10.00/-<br>From 04 Kms to 08 Kms Rs. 15.00/-<br>From 08 Kms to 12 Kms Rs. 20.00/-<br>Above 12 Kms Rs. 25.00/- |
| **2** | **E-Rickshaw –- Service** | Available from 30 stations<br>295 e-rickshaws are being run as of now<br>From starting of metro services until the closure of metro services<br>Fares:<br>For first 2 Kms Rs. 10/-<br>Thereafter for subsequent km. Rs. 5/- |
| **3** | **Cab Aggregator –- Service** | Available at 50 stations<br>From starting of metro services until the closure of metro services |
| **4** | **E-Scooter –- Service** | Available at 05 stations<br>30 e-scooters are available as of now<br>Operates Round the clock<br>Fares:<br>Rs. 01/- per minute<br>Rs. 50/- for one hour<br>Rs. 120/- for one day |
| **5** | **Cycle Sharing –- Service** | Pedal Cycles are Available at 11 stations<br>Battery-operated cycles available at 41 stations<br>994 Cycles (battery & pedals) are available as of now<br>Fares:<br>For Pedal cycles<br>Rs. 05/- for 30 mins (only at Rohini East, GTB Nagar & Vishwavidyalay metro stations)<br>Rs. 10/- for first two hrs & Rs. 10/- for every subsequent hour (for remaining all stations)<br>For battery-operated cycles<br>Rs. 10/- for 10 mins. |

Source: Delhi Metro




Source: Delhi Metro

**Figure 15-7: Last Mile Connectivity Strategy Web Page by Delhi Metro**




Source: JST

**Figure 15-8: Delhi Metro Station with Feeder Buses**

### 15.12.3 Interview Survey

#### (1) Interview of Autorickshaw Drivers

In July 15 2022, at four (4) major Auto Rickshaws Stands listed below, 30 autorickshaw drivers were asked to cooperate an interview about their opinions about the Project.

1. Patna Junction Railway Station (Corr. 1-10, Corr. 2-1)
2. Gandhi Maidan (Corr. 2-3)
3. Saguna More (Corr. 1-2)
4. Mithapur (Corr. 1-11)

The drivers were first given general information about the Patna Metro Rail Construction Project, including its routes, expected commencement timing, expected positive impacts on reducing the traffic jam on the road, and potential competition for customers in the operation phase. Then the drivers were asked about their opinion what kind of impact the Project will bring their work and living.

The survey results are summarized in the table below.

**Table 15-75: Interview of Autorickshaw Drivers**

| **Question asked** | | • When the Patna Mero starts operation in near future, do you think your business environment will be better, or do you think your sales will reduce because of the competition for customers? |
|---|---|---|
| **Answers** | **Number** | **Opinion About the Project** |
| Positive opinion | 29 | • After the implementation and proper running of Metro Rail, drivers will travel for shorter distance per customer, hence they could do more trips with similar cost.<br>• When the auto stands are prepared at Metro Stations, the number of the auto stands increase in the city, that is benefit of the drivers.<br>• Metro Rail will help reducing road jamming and Road accidents. Traffic congestion and honking is major problem which make fatigues to Patna citizen and reduce the work efficiency. |
| Neutral opinion | 1 | • Can not decide now whether positive impacts or negative impacts will affect more on my operation |
| Negative opinion | 0 | - |

Source: JST




Source: JST

**Figure 15-9: Interview of Autorickshaw Drivers**

### (2) Interview of Institutions Related Bus Operation

Opinions from a bus operator (BSRTC (Bihar State Road Transport Corporation)) and the governing office (District Transport Office) were collected by interviews. The results are shown in the table below.

Bus transportation in Patna started in the year 2018. Before that, auto rickshaws were the main mode of transportation for the residents, besides walking, cycling, and motorcycles.

Both offices consider that the reduction of traffic jam by opening the Patna Metro will be a positive impact for their operation. No negative response regarding decline of sales were expressed. At the same time, it seems that the BSRTC has not developed operation plan including Patna Metro under operation, and the BSRTC is simply considering increase of number of operating buses in near future.

**Table 15-76: Interview of Institutions Related Bus Operation**

| Interviewed Institution | Opinion |
|---|---|
| District Transport Office | ➢ The Proposed Metro Project will reduce the pressure of vehicles on the road<br>**Other obtained information:**<br>➢ There are no Bus and Auto Operators Associations or Unions operating in the city.<br>➢ Transport authorities are proposing to Plan Zones in the city for Auto operators. |
| BSRTC (Bihar State Road Transport Corporation) | ➢ Bus Passengers are very eager to welcome the Patna Metro Rail Construction Project as they are facing the trouble of traffic jam and crowded buses.<br>➢ Bus drivers are also willing to welcome Metro as they are expecting reduction of traffic on road.<br>➢ No response was obtained any strategy to be taken after the operation of Metro Project.<br>**Other obtained information:**<br>**Operation started**<br>In the Year 2018.<br>**Total Number of Buses operating in the city**<br>PPP Mode: 130 Buses<br>Nigam (co-op type operation): 90 buses<br>Electric Buses: 25<br>(In addition to above, about 350 private buses are operated in Patna)<br>**Number of Passengers**<br>Electric Bus Passengers: 6000/ Day<br>City Bus Passengers: 32,000/ Day<br>**Number of Trips/Day**<br>4 up and 4 Down<br>**Number of Routes/Day**<br>Buses Travel to Rajendra Nagar, Kankarbagh, Shri Krishna Puri, Patliputra, Gandhi Maidan, Danapur, All India Institute of Medical Sciences, Patna University, Patna Sahib, Saguna Mor, Hajipur, Manersharif, Bihta and Digha.<br>**Future Plans of BSRTC**<br>The addition of 75 buses are proposed ( 50 Electric Buses and 25 CNG Buses) |

Source: JST

### 15.12.4 Proposals for the Development of Urban Transportation Network

Based on above studies, following strategies are proposed for establishment of better urban transportation network in Patna. By implementing the following measures in cooperation with related organizations, a more efficient urban transportation network will be realized while maintaining the operation of existing transportation facilities.

Since the future network can not be realized by PMRCL alone, it is expected that the Department of Urban Development and the Department of Transport are expected to take the initiative in developing and implementing these strategies.

1. Route Buses on artery roads will be shifted to feeder routes that connect residential areas/villages more than 500 m from Metro stations.

2. Auto rickshaws and rickshaws will maintain operations by emphasizing the function of the last one mile linking between stations and residences or workplaces within 2 km, while avoiding congestion and congestion on arterial roads.
3. Drop/pick-up zones, parking lots, transfer information boards, etc. will be developed in line with metro development, and contribute to the creation of orderly road spaces and to ensure the integrity of public transportation services.
4. Department of Urban Development and the Department of Transport will take the leading role of coordination meetings and planning for planning and implementation of above three strategies together with PMRCL, bus and taxi operators, and representatives of auto-rickshaws operators.
5. By introducing standardized payment systems, the discounted fare for combined trips, MaaS (Mobility as a Service) concept, public transportation service will be integrated and be easier to use and more efficient for customers.

## 15.13 Survey on Necessity of Indigenous Peoples Plan

As per the Census in 2011 by the Government of India, Patna City has 72 wards through which both Metro corridors are passing. There are 5,139 persons who belong to indigenous people receding in all 72 wards of Patna City.

In the surveys for DPR SIA in 2020 implemented by DMRCL, and for the state SIAs implemented in 2022, no indigenous persons were recognized among PAHs/PAPs. During the site visit by the local consultant in July 2022, no sign of indigenous person's residences were recognized along the 2 Corridors.

With the Above information and observation, it can be concluded that the Project does not require an Indigenous Peoples Plan.

## 15.14 Consideration on Gender

### 15.14.1 Analysis

#### (1) Politics and systems

Central government of India has been working on to secure equal legal rights for men and women as shown in the following table.

The most recent moves are the Women's Reservation Bill in 2016 by the Central Government, and the State of Bihar policy issued in the same year. The Central Government Bill states 30 % quota for women in governmental and private employment. State of Bihar announced additional 5 %, a reserve of 35 % of all government jobs, and engineering, medical, and technical education colleges jobs for women. Further, State of Bihar declared that a 50 per cent reservation for women in teaching jobs, police, and the panchayats.

As of September 2022, PMRCL, which was established in 2019, has not yet developed a gender action plan.

**Table 15-77: Gender Related Acts and Policies**

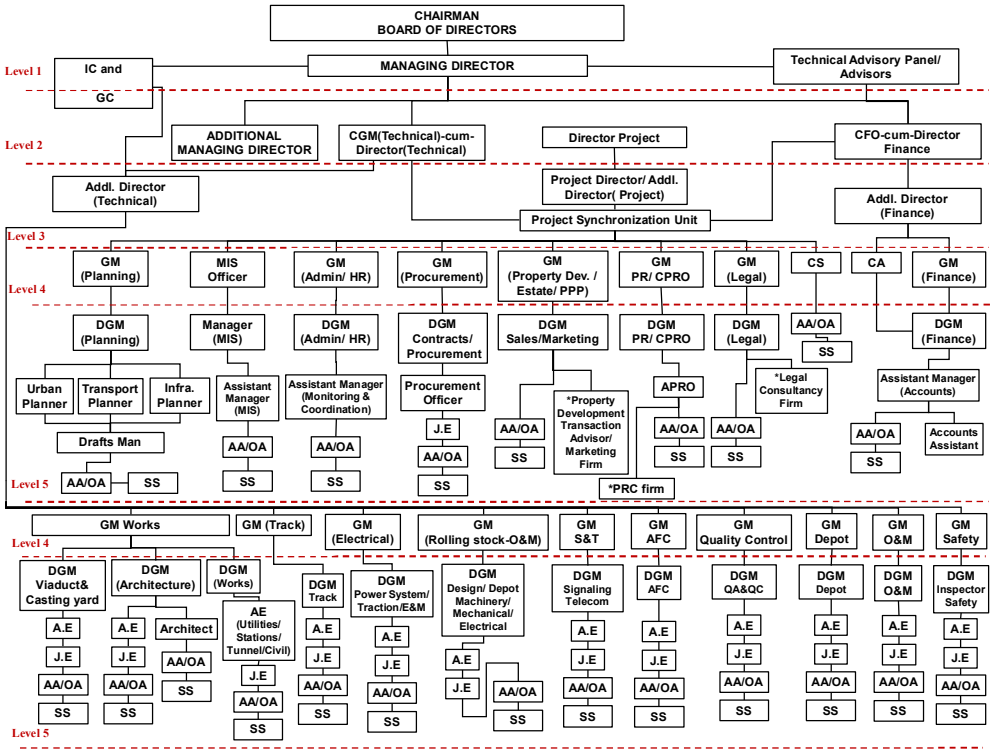
| | |
|---|---|
| **Laws prohibiting gender-based violence and harassment** | • **Dowry Prohibition Act, 1961:** Penalty for giving or taking dowry.-Penalty for demanding dowry.-Dowry to be for the benefit of the wife or heirs.<br>• **The Sexual Harassment of Women at Work Place (Prevention, Protection and) Act, 2013:** internal complaints committee, local complaints committee, duties of employer, duties and powers of the district officer |
| **Legal systems related to resettlement and compensation** | • The Hindu Women's Right to Property Act, 1937: the property rights of Hindu widows.<br>• **The Hindu Succession (Amendment) Act, 2005:** Hindu women's the right to be coparceners or joint legal heirs in the same way a male heir. Property rights are very complex under Muslim law. |
| **Labor law** | • **The Equal Remuneration Act, 1976:** application of equal pay for women and men |
| **Female quota** | • **Constitution 1993:** The constitutional amendment stated that a random one- third of village council leader, or Sarpanch, positions in the gram panchayat should be reserved for women.<br>• **Women's Reservation Bill 2016:** The bill seeks to reserve 33% of seats in Lok Sabha and all state legislative assemblies for women, and reservation of 30 % for females in the employment of any government and private organization. The quota is mandated at each level of the staff, therefore, the employer is required to provide equal trainings as well as promotions to female and male staff. Reservation of seats for women shall cease to exist 15 years after the commencement of this Amendment Act.<br>• **The policy of State of Bihar 2016:** will reserve 35 % of all government jobs, and engineering, medical, and technical education colleges for women. A 50 per cent reservation for women in teaching jobs, police, and the panchayats. |
| **Encouragement of female entrepreneuership** | • Stand Up India Scheme 2016:<br>➢ **Objectives:** to support entrepreneurship among women and Scheduled Caste & Scheduled Tribe communities who for the first time start business enterprise (Greenfield enterprise).<br>➢ **Support:** in setting up enterprises, obtaining loans and other support needed from time to time for succeeding in business.<br>➢ **Bank loans** (including term loan and working capital): between INR. 10 lakh (US$ 14,000/ about JPY. 2 million) and INR. 1 crore (US$ 140,000/ about JPY. 20 million)<br>➢ **Target sectors:** manufacturing, services, agri-allied activities or trading.<br>• **Supporting Bank in Bihar**: Punjab National Bank, Patna |

Source: JST

## (2) Female employment in Organizational structure of PMRCL

PMRCL was established on February 19, 2019 for the implementation of the Patna project. The organizational chart of the Patna Metro Company is shown in Figure 15-10**.**

PMRCL has 188 posts already approved by the Bihar Urban Development and Housing Authority, and 41 posts are already filled as of September 2022. Out of the total 41, 5 positions are filled by female staff. Their positions are Accountant, Data Entry Operator, and supporting staff (SS) at GM (Administration & HR) office. There are no Engineer level officers or above positions filled by female employee yet.




Source: PMRCL／DMRC

**Figure 15-10: Organization Structure of PMRCL**

### (3) Observation and Requests of Female Passengers on Public Transportation in Patna

In Patna, priority seats are available for women customers on the buses at the front part of the coach behind the driver. Indian Rail also provides women-only cars on every train.

During the field observation, female customers on buses and auto-rickshaws were seen regularly, although the number was less than male passengers. In addition, both male and female students of 50 universities and colleges located in Patna were seen walking in groups on main streets in Patna. Those students, including 3 women's college students and female students in co-education universities and colleges, can be a potential commuting customers of Patna Metro.

In July 2022, passengers at busy traffic points were interviewed for desirable services for female customers at Patna Metro in operation phase. The interviews were conducted at all 24 proposed station locations, and 5 females in various ages were selected as interviewee at every location. During the interview, 75 % of interviewee requested separate Female coaches on the Metro train, and the remaining 25% wanted special seats secured for women on general coaches. Other requests expressed by female potential metro users are listed below.

1. Separate Female-only Car and separate places on the platform
2. Reserved seats for senior female passengers on the Female-only Car
3. Breast feeding room
4. Waiting room for women passengers at the station where they rest, and can feed their child
5. Female traveller concession in tickets and monthly pass
6. Female-only Que at the ticket counters

To generate mentally and physically safe environment for the female interviewee to answer to the unknown interviewers, following measures were taken in this survey: the focus group discussion for women was led by female researchers; a group of women were selected as interviewee to avoid negative feeling of the interviewee to be singled out for unknown situation; two female interviewers worked together as the interviewer with two male researchers watching from a distance for the security of the female interviewers ; and the proof photos of the interview were taken from a distance so that the female interviewee do not feel uncomfortable by being photographed.

Same, and similar measures are recommended to be taken by PMRCL when PMRCL conduct monitoring and perception survey of female customers in the future.

### (4) Gender Integration Efforts by Other Metro Projects in India

JST collected information on 15 metro projects in India regarding design and activities on gender integration. Multiple metro corporations have ambitious plan to hire female staff for various positions.

**Table 15-78: Gender Integration Efforts by Other Metro/Rail Projects in India**

| Timing and Issues | Gender-related Strategies |
|---|---|
| **Station Design** | • Women help desk is located in stations. |
| **Employment in Construction Phase** | (no information was available) |
| **Employment in Operation Phase** | • 25 % of train operators are female staff.<br>• The corporation is aiming that 80 % of the staff to be female. |
| **Operation of Rolling Stock** | • Every train, throughout the day, one car (32 seats) out of 6 or 8 car-train is dedicated for female passengers.<br>• Every car has seats secured for women passengers.<br>• Every car has seats secured for elderlies, women, and differently-abled persons.<br>• Half of one car is secured as Ladies Zone in one train.<br>• In the rush hour in the morning and the evening, one train reserved for female passengers are operated. |

Source: JST




Pink color showing female coach, Indian Railways




Female driver, Kochi Metro




Female queue sign, Namma Metro




A tape dividing a car in Ladies only zone, Hyderabad

Source: https://www.financialexpress.com/infrastructure/railways/unique-initiative-for-women-safety-indian-railways-nfr-zone-earmark-coaches-with-pink-for-easy-identification/1661659/
https://gulfnews.com/world/asia/india/indian-women-drive-change-on-kochi-metro-1.63054776
https://timesofindia.indiatimes.com/city/bengaluru/women-cheer-throng-reserved-metro-doors/articleshow/62991644.cms
https://www.thehindu.com/life-and-style/the-ladies-compartment-on-the-metro-is-yet-to-become-an-exclusive-space-that-keeps-men-out/article24013728.ece

**Figure 15-11: Gender Integration Efforts by Other Metro/Rail Projects in India**

### 15.14.2 Proposals for Gender-Responsive Activities

#### (1) Gender considerations in station design

It was confirmed from the tender drawings and questions and answers that the station facilities have the gender and infant considerations listed in the table below.

Additionally, JST proposed that 1) all stations should have a women's helpline desk staffed by women from the police or PMRCL security departments; 2) crime prevention measures must be installed such as monitoring of underground passes and areas near to the station entrances with CCTV, and good lighting to eliminate dark areas; 3) emergency hot lines must be installed on the train as well as at multiple locations of the station, and be connected to the security stations or local police stations.

**Table 15-79: Patna Metro Station Facility Gender and Infant Design Consideration Plan**

| Facility | Gender and Infant considerations |
|---|---|
| Toilet separated male and female | The toilets are to be install for passengers and station staff in all station paid concourse area. Moreover, gender-segregated toilets for station staff in some station back-office areas. |
| Transgender toilet | The transgender toilet is to be installed alongside passenger toilet areas in the concourse are at some stations. Transgender people can use the toilets without having to worry about the stares of others which they felt when using the Male or Female toilets. |
| Diaper-changing tables | The diaper-changing table is to be install in multi-purpose toilets of a part of some stations. By installing the table in multipurpose toilets that can be used by both men and women |
| Separate security gates | Two lines of security gates to be installed at all stations that are planned as separate rows for men and women. In addition, a women's body search area is planned with a curtain to prevent women from being seen by others. |
| Platform | The platform is designed to have a good view and to eliminate blind spots, thereby preventing and controlling crime and allowing female passengers to use the platform safely. |

Source: JST

### (2) Employment in Construction Phase

As stated in Section 15.1, according to the Periodic Labour Force Survey (MoSPI) NSO 2018, Bihar registered the lowest female labour force participation rate (LFPR) at merely 4% in rural areas and 6.5% in urban areas. One of the reasons for such a low level of female LFPR in Bihar has been the traditional social norm of limiting female role within household, and not encouraging female population to go out of house to take part in the labour force.

During the Site assignment of JST in Patna and State of Bihar, many road maintenance work sites were observed, but female construction workers were rarely seen. Compared to other locations in India, female workforce participation especially as unskilled construction laborers may be resented in State of Bihar.

On the other hand, PMRCL, as a part of State of Bihar institution, confirmed in a meeting with JST that PMRCL has the responsibility of implementing equal recruitment for any level of workers and staff. PMRCL also confirmed that it is aiming to achieve the 35 % of female quota in the long run.

### (3) Employment in Operation Phase

PMRCL is planning to start operation in 2028. Recruitment activities for operation staff has not yet started. In the beginning phase of operation, it can be expected that many DMRCL trained staff will be rented to PMRCL for smooth operation and for the training of newly hired staff of PMRCL.

PMRCL, as a part of the State of Bihar institution, has the responsibility of implementing equal recruitment for any level of workers and staff, and the responsibility to achieve the 35 % of female quota.

### (4) Operation of Rolling Stock

PMRCL is planning to operate 3-car train in the beginning of their operation. After the good number of customers are secured, PMRCL will operate 6-car train.

Understanding the strategy above, JST has proposed PMRCL to secure female seats in the following manner. Female-only seats must be secured throughout the operation hours. The number of secured seats will vary depending on the number of cars on a train. PMRCL responded on September 13, 2022, that the proposal will be taken into consideration.

**Table 15-80: Proposal of Female-Only Seat Number and Availability**

| Number of cars in a train | Availability of seats secured for felame passengers | Seat number secured |
|---|---|---|
| On 3-car train | On every train throughout the operation hour | 1 car |
| On 6-car train | On every train throughout the operation hour | 1 car |

Source: JST

### 15.14.3 Monitoring Plan for Female Participation and Gender Integration Through Operation of Patna Metro

#### (1) Proposed Monitoring Plan of QOL and Customer Satisfaction

Monitoring QOL indicators and conducting Customer Satisfaction Survey for metro passengers during project implementation is recommended to verify the positive impact of the Project for the local community. The purpose of QOL monitoring is to measure the impacts of the Project to the general public in Patna, and the Customer Satisfaction survey is to receive feedback from passengers to improve the quality of services.

During the implementation, PMRCL is expected to be responsible for monitoring through the annual survey. DMRC has experiences of conducting a customer satisfaction survey since 2013, and their survey method would be a considerable reference to PMRCL.

The composition of the survey target must be equally distributed among male and female samples. Survey results must not only be analyzed in total, but also separately for male and female results. In addition to the gender consideration, the survey targets must cover all the walks of life, reflecting the diverse social composition in Patna.

The main questionnaire in the surveys are listed in Table 15-81.

In addition to such survey, opinions of Metro users/passengers received in opinion boxes or via web site, email, etc. must also be analyzed in gender-disagregated manner in numbers and the contents.

Such monitoring and survey are valuable chance for PMRCL to contribute the female population in Patna, Bihar to express their opinions and to participate in local decision making process.

**Table 15-81: Overview of QOL Monitoring and Customer Satisfaction Survey**

| | |
|---|---|
| **Target** | A few thousand passengers using Patna Metro, with equal number of male and female samples |
| **Frequency** | Once a year |
| **Method** | Online and household interview survey |
| **QOL Indicators** | • Household income and expenditure<br>• Access to social services (office, school, hospital, shopping centre, etc.)<br>• Current satisfaction level of QOL (access to bus stop, office, school, hospital, shopping centre, housing conditions, traffic safety, green environment, air pollution, noise, etc.)<br>• Importance of QOL items |
| **Customer Satisfaction Survey** | Satisfaction level of metro (availability, accessibility, affordability, facilities, information, customer service, security, safety including women only cars, environment impact) |

Source: JST

#### (2) Proposed Monitoring Indicators for Assessing the Organizational Gender Integration

The following 27 indicators were proposed for PMRCL in monitoring the level of achievement of gender

integration in its organization. Once a year evaluation in the early phase of budget discussion for the next fiscal year is recommended to monitor the achievement of the year, and to identify the next step forward with secured budget. This internal survey is desirably led by female leader, with equal number of male and female staff in the survey team, since gender issues such as capacity development of female staff are not only the female issue, but rather the issue of male mindset.

**Table 15-82: List of Gender Indicators for Monitoring of Gender Integration**

| | **Policies and systems** |
|---|---|
| PMRCL | 1. Gender Action Plans formulated |
| | **Organizational structure** |
| PMRCL | **[Gender training for executives and staff]**<br>2. Number of gender-training sessions for executives and staff<br>3. Number of training participants (by gender and age)<br>4. Change in gender awareness after training<br>**[Female executives]**<br>5. Increase in the number and percentage of female executives<br>6. Percentage of quota to increase female executives (planned and actual)<br>**[Female staff and technicians]**<br>7. Increase in the number and percentage of female staff and technicians<br>8. Percentage of quota for active employment of women (planned and actual)<br>9. Personnel policy for active recruiting of women (content)<br>**[Work environment]**<br>10. Details of improved work environment<br>11. Satisfaction level of female employees with the work environment<br>**[Strengthening the capacity of female technicians]**<br>12. Participation status in various training programs (by gender)<br>13. Identified training needs of female technicians and staff<br>14. Enhanced competencies and skills of female technicians<br>**[Harassment and SGBV in the workplace]**<br>15. Number of reports of harassment and SGBV (Sexual and gender based violence) in the workplace (by type)<br>16. Number of incidents of harassment and SGBV in the workplace (by type)<br>17. Training on harassment and SGBV (number of times conducted, number of participants (by gender))<br>18. Changes in staff understanding and awareness of harassment and SGBV<br>**[Participation in decision-making]**<br>19. Increase participation of female members in the Committee for Gender Action Plan<br>20. The Gender Action Plan Committee is held in the timing and hours easy to participate for female members<br>21. Gender-specific needs incorporated in Gender Action Plans |
| | **Project Impact on Gender Empowerment** |
| RAP Implementation (Rehabilitation after resettlement) | **[Women's participation in technical training]**<br>22. Increase in the number and percentage of female residents who participated in technical training<br>23. Techniques and skills acquired by women |
| PMRCL/DMRCL | **[Employment of women]**<br>24. Number and percentage of women employed for the project (civil, construction, canteen, other skilled/ unskilled labour) |

Source: JST

## 15.15 Differently Abled Persons

### 15.15.1 Policies, Laws, and Programs Related to Differently Abled Persons

Barrier free measures in station facilities is designed in accordance with "Harmonised Guidelines and Space Standards for Barrier Free Built Environment for persons with Disability and Elderly Persons in the year 2016" the barrier free guidelines issued by the Ministry of Urban Development of India, and the Barrier Free Standards for Station Facilities of the National Building Code of India (NBC2016).

The station facilities plan to be designed with consideration for persons with disabilities (physical, visual, hearing, internal diseases, etc.) in accordance with the guidelines and basic code that is confirmed in the Station Building design report.

### 15.15.2 Already Incorporated Measures

The lists shown in the table below are the design criteria for barrier free design that is mentioned the Station Building design report.

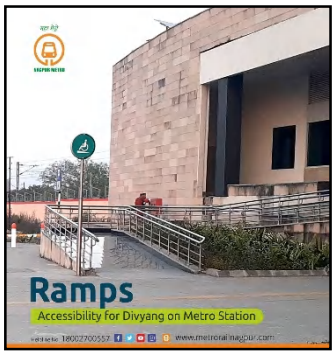
In addition, with the lead of the Department of Urban Development and Housing of State of Bihar, which is the managing office of PMRCL, and the District Transport Office, the road space around the stations will be re-coordinated with safety measures such as traffic signals and crossing zones.

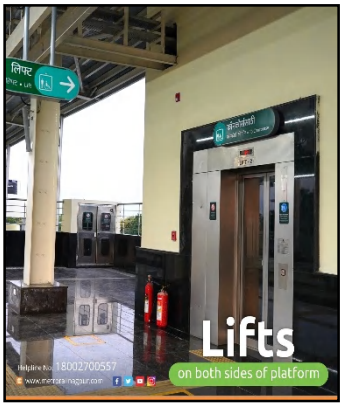
**Table 15-83: Patna Metro Station Facility Barrier-Free Design Criteria**

| Facility | Criteria |
|---|---|
| Station Entrances and Exits | • The station entrance/exit should not have a difference in level. If a level difference is unavoidable, install a ramp or a ramp plus staircase.<br>• It is desirable that space be marked out near the station entrance/exit for vehicles carrying wheelchair users. |
| Reservation or Information Counters | • Reservation or information counters should have unobstructed approaches for wheelchair users.<br>• One counter height should be 750 mm. |
| Concourse | • The concourse should not have a difference in level. If a level difference is unavoidable, install a ramp or a ramp plus a staircase.<br>• The floor surface of a concourse should be made of non-slip material. At places, where the difference in level such as stairs, it is desirable that the appearance of the surface material be changed using a color contrast.<br>• Install guiding blocks on the concourse for persons with impaired vision.<br>• Wherever columns exist, an electrical/ fiber-optic/ equivalent provisions shall be made keeping in mind the future of having revenue-generating facilities as ATMS and also facilities for ease of passengers (coffee/ tea vending machines). |
| Staircase | • For details, see the guidelines for staircases as per Part 4 'Fire & Life Safety' & Annexure J of NBC 2016 (including amendment 1 issued in March 2021). |
| Lifts (Elevators) | • Install a lift (elevator) to enable passengers with disabilities to move between floors.<br>• For the lift (elevator), install one warning block for persons with impaired vision 300 mm away from the call button. |
| Toilets | • Install a toilet and washstand suitable for use by wheelchair users and other passengers. |
| Ticket Gates | • One of the ticket gates should have a continuous line of guiding tactile blocks for persons with impaired vision. |
| Platforms | • The platform should have one row of dotted guiding blocks for persons with impaired vision, 800 mm or more from the edge.<br>• The paved surface of the platform must be made with a non-slip material<br>• Stairs, kiosks and dustbins on the platform must not hinder the clear passage of persons with impaired vision and wheelchair users.<br>• A bench should be installed on the platform, having guiding block around it. |

| Facility | Criteria |
|---|---|
| Rolling Stock (Car) doors | • Car doors should be wide enough for wheelchair users (minimum 900 mm)<br>• The gap between car doors and the platform should be reduced to an absolute minimum. |
| Information | • The information board should be made easily readable by using sufficiently large text size, distinct contrast and illumination.<br>• It is desirable that in addition to a printed version of the train schedule, table of fares and other travel information also be in Braille. |

Source: PCDD 01: Design Basis Report April 2022

<table>
<tr><td>
</td><td>
</td></tr>
<tr><td>Wheelchairs are available at the Customer Care Counter at every station</td><td>Ramps are installed in metro stations wherever surface level changes</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Wheelchair Parking space available at all the Metro Stations</td><td>Seats are reserved for differently abled/senior citizens.</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>Well lit signage at appropriate places to inform about various facilities like elevator, entry, exit and accessible toilets etc.</td><td>Flap gates can be opened extra-wide to allow wheelchairs through.</td></tr>
</table>

| | |
|---|---|
|  |  |
| Audio system at elevators (lifts) announces the door closing/opening, next reaching floor number, and arrived floor number. Train doors have audio and visual systems that tells next station, arriving station, door opening side. | Station staff constantly monitors passenger movement and provides personal help to any differently-abled person who needs assistance. |
|  |  |
| On all the metro station floors tactile pathways have been made to help guide the persons with visual impairment. These paths do lead people right to the places like ticket counters, toilets, platforms etc. | All the Metro Station is equipped with elevators (lifts) which reach at all the levels with wheelchair. |

Source: Nagpur Metro

**Figure 15-12: Sample Photos of Barrier-Free Design for Station Facility**

### 15.15.3 Newly Proposed Measures

When a person with a Unique Disability ID or disability Certificate travels with Indian Rail, the ticket will be sold at 25 % of the regular price for him/her and 1 attendant. In the future, it is recommended that similar price adjustment be installed at Patna Metro to encourage social and economic participation and integration of all.

# 16. Public Consultation[54]

## 16.1 1st Public Consultation

### 16.1.1 Overview of PCs implemented by PMRCL PCs

PMRCL conducted Public Consultations (PCs) from May 27th to 30th, 2020. Prior to the holding of the PCs, PMRCL notified local residents including affected households on May 8th, but the PCs were forced to be held in a small number of people taking basic measures; wearing masks, keeping social distance, and disinfecting, because the mass gathering was restricted due to the COVID-19. At the PCs, PMRC explained about land acquisition, affected structures, high-risk environmental and social considerations items, the existence of important common resources, considerations for vulnerable groups, mitigation measures for affected assessment items, affected asset value, and other assistance/allowance to have the discussions with the local residents.

### 16.1.2 Implementation method and approach of PC held by PMRCL, and summary of results

The PCs were held by PMRCL for affected people in various sectors such as traders, women groups, and other residents related to the affected areas. On the PCs, discussions were held on land acquisition, compensation for them, livelihood restoration, job creation, information flow, grievance redress mechanism, safety, and the role of government. In the resettlement action plan, PMRCL will propose to deal with all the problems raised in the PCs and to strengthen the countermeasures for those problems in the future. PMRCL adopted the following method when implementing the PCs.

- On May 8, 2020, notifications were given that PCs would be conducted in several locations in the vicinity of the affected areas.
- PCs were held in the vicinity of the affected area along the Corridors. (from May 27 to 30, 2020)
- Sharing priorities and opinions of affected people

In addition, PMRCL explained to participants the summary of the EIA report and the project outline, including environmental baseline data, anticipated environmental impact items, and mitigation measures, and the participants were asked for their opinions and suggestions. The PCs were held at Rukanpura, Raja Bazar, Zero Mile, Gandhi Maidan and Bigrahpur (Mithapur). In the PCs, since the land acquisition by the project implementation and itself has severe impacts on the affected people who will lose their land, they raised their opinion that it should be compensated at the market price. There was also an opinion that the lessees should be fully compensated because they have severe impacts on their lives, too. On the other hand, they had a great interest in the project, and raised their opinions that they wanted youths to be hired with full-time. The outline and discussion content of the PCs in each venue are as follows, and the detailed discussion's content are attached as Attachment 10

[54] Environmental Impact Assessment and Social Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Table 16-1: Summary of PC Results Conducted by PMRCL (1)**

| Item | Content |
|---|---|
| Date | 27th (Wed) May, 2020 |
| Venue | Rukanpura |
| Participants | 3 persons (3 males) |
| Main opinions from participants | Q1. Private land should be avoided.<br>Q2. What kind of measures will be taken to prevent dust generation during construction?<br>Q3. There is concern about noise generated by heavy machinery operation.<br>Q4. Income loss during construction should be also compensated. |
| Replies from PMRCL | A1. Please understand that it is necessary to acquire private land due to restrictions on land acquisition as project land.<br>A2. Regular water sprinkling, especially in the dry season should be proposed in order to control the dust diffusion.<br>A3. Perform regular maintenance according to the passed time from the machinery manufacturing. In addition, operation arrangements should be conducted so that the heavy machinery operation does not overlap in order to reduce the cumulative impact.<br>A4. Scrutinize the issue referring the Land Acquisition Law (2013). |

Source: Environmental Impact Assessment and Social Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Table 16-2: Summary of PC Results Conducted by PMRCL (2)**

| Item | Content |
|---|---|
| Date | 27th (Wed) and 30th (Sat) May, 2020 |
| Venue | Raja Bazar |
| Participants | 7 persons (6 males, 1 females) (PCs held in 3 times) |
| Main opinions from participants | Q1. There is concern about dust and smoke generated during construction.<br>Q2. Shops and tenants must be relocated due to the project.<br>Q3. The project will induce traffic congestion during construction.<br>Q4. Income loss during construction should be also compensated for PAHs that lose their partial land.<br>Q5. Compensation for individual shop owners and tenant owners. |
| Replies from PMRCL | A1. Regular water sprinkling, especially in the dry season should be proposed in order to control the dust diffusion. Other mitigation measures related to air pollution are mentioned in the EMP.<br>A2. The issue should be considered when paying compensation and allowances, but the payees include both owners and lessees.<br>A3. The construction activities will be implemented underground and within barricades. Traffic management will be planned in consultation with the traffic police.<br>A4. Scrutinize the issue referring the Land Acquisition Law (2013).<br>A5. The issue should be discussed at the payment time, but they may also be included as eligible persons. |

Source: Environmental Impact Assessment and Social Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Table 16-3: Summary of PC Results Conducted by PMRCL (3)**

| Item | Content |
|---|---|
| Date | 29th (Fri) May, 2020 |
| Venue | Gandhi Maidan |
| Participants | 8 persons (8 males) |
| Main opinions from participants | Q1. Relocation site and rehabilitation as social consideration items.<br>Q2. There is concern about dust and smoke generated during construction.<br>Q3. There is a concern about leaving the excavated soil which will be traffic obstacles.<br>Q4. Due to livelihood of three wheeler's driver in the same place for a long time, they are worried about losing their income during construction and operation.<br>Q5. Relocation site and livelihood restoration. |
| Replies from PMRCL | A1. Relocation and rehabilitation will be implemented according to the entitlement matrix.<br>A2. Adaptation of mitigation measures for air pollution.<br>A3. To prohibit construction contractors from leaving construction waste and to instruct them to transport it to disposal sites on a regular basis.<br>A4. Compensation and livelihood restoration support will be implemented according to the entitlement matrix.<br>A5. Scrutinize available alternatives in the vicinity based on relocation and livelihood restoration support policies. |

Source: Environmental Impact Assessment and Social Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Table 16-4: Summary of PC Results Conducted by PMRCL (4)**

| Item | Content |
|---|---|
| Date | 29th (Fri) May, 2020 |
| Venue | Bigrahpur-Mithapur |
| Participants | 16 persons (16 males) |
| Main opinions from participants | Q1. Since there is a concern about noise generated during construction and operation, it should be controlled.<br>Q2. To propose the alignment review.<br>Q3. Since debris is generated even in small-scale construction, a large amount of construction waste will be generated in such a large-scale project.<br>Q4. There is a concern about the compensation amount.<br>Q5. Income loss during construction should also be compensated. |
| Replies from PMRCL | A1. PMRCL will implement mitigation measures again Station noise generation during construction and operation.<br>A2. Alternatives have already been considered and then the alignment was finalized.<br>A3. To prohibit construction contractors from leaving construction waste and to instruct them to transport it to disposal sites on a regular basis.<br>A4. Compensation for landowners, tenant users, etc. will be implemented within the policy of relocation and restoration support.<br>A5. Scrutinize the issue referring the Land Acquisition Law (2013). |

Source: Environmental Impact Assessment and Social Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Table 16-5: Summary of PC Results Conducted by PMRCL (5)**

| Item | Content |
|---|---|
| Date | Not mentioned |
| Venue | Zero Mile |
| Participants | 6 persons (6 males) |
| Main opinions from participants | Q1. There is no major concern from kiosk officials located at the government land that has to be relocated. But was the avoidance of relocation examined?<br>Q2. There is concern about dust and smoke generated during construction. |
| Replies from PMRCL | A1. Compensation will be implemented within the Policy and Regulated Framework.<br>A2. Regular water sprinkling, especially in the dry season should be proposed in order to control the dust diffusion. Other mitigation measures related to air pollution are mentioned in the EMP. |

Source: Environmental Impact Assessment and Social Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC




Source: Environmental Impact Assessment of Danapur - Mithapur- Khemni Chak and Patna station-New ISBT, Jul, 2020, DMRC

**Figure 16-1: PC Photos of 1st PC**

## 16.2 2nd Public Consultation

### 16.2.1 EIA

Public consultation for EIA in the presence of the residents has been held at Khemni Chak, New ISBT, R.P.S. More, Raja Bazaar, Rajendra Nagar and Patna Station where it is easier for the residents to gather along the Patna Metro Corridors. In the consultations, the project outline, the expected environmental and social impact items from the project, the survey results on the environmental and social impact, the environmental management plan, and the environmental monitoring plan have been explained. The participants asked questions about the construction period and underground depth, requested that the construction be carried out in environmental consideration, and expected new employment for construction work, business opportunities, and discounts on train tickets etc. On the other hand, during consultations at the sections under construction, there were complaints about dust generation, worsening traffic congestion worsening traffic congestion caused by construction vehicles, and delays in construction etc. PMRCL carefully responded to each question and complaint, and the consultations ended without any major issues. The summary of the result of 2nd Public meeting is shown below, and the minutes of meeting at 6 location and the participant list are attached as an Attachment 11.

**Table 16-6: Summary of the Result – 2nd Public consultation**

| Item | Contents |
|---|---|
| Date & Venue | Khemni Chak : Jharokha Banquet, 5th Sep 2022 10:00 – 12:00<br>New ISBT : Umrao Hotel, 5th Sep 2022 14:00 – 16:00<br>RPS More : Heritage Garden, 6th Sep 2022 10:00 – 12:00<br>Raja Bazaar : Matri Hotel, 6th Sep 2022 14:00 – 16:00<br>Rajendra Nagar : Panasia Hotel, 7th Sep 2022 10:00 – 12:00<br>Patna Station : Samrat International, 7th Sep 2022 14:00 – 16:00 |
| Language | Hindi |
| Announcement method for the meeting | Announced by PMRCL to the residents through the media 10 days ago |
| Consideration for the holding | To notify that not only the householders but also all residents such as women and vulnerable groups can participate. |
| Participant | PMRCL: Mr. S. S. Prashad<br>DMRC: Mr. S. N. Pandey<br>JICA Study Team: Mr. Ashish Kumar<br>Sub-Consultant: Mr. Ankur Agarwal, Dr. Shiv Prakash Singh, Mr. Miland Joshi<br>228 local peoples (Male: 213, Female: 15) |
| Main opinion from local people | Q1. The negative impacts, their precaution measures and public benefits of the project<br>Q2. Contact for complaints<br>Q3. Length of construction period<br>Q4. The environment development work should be continued.<br>Q5. Plantation should be done as like Delhi.<br>Q6. Where are the final details where we can confirm that which place is going to be affected or not?<br>Q7. What will happen to the houses and wells on the route of the underground section?<br>Q8. Depth of underground construction<br>Q9. Provision for people who lose their jobs because of this project<br>Q10. Access to store blocked by construction barricades<br>Q11. Information disclosure and updates to local citizens<br>Q12. How to apply to open a small store in a station |

| Item | Contents |
|---|---|
| | Q13-1. After the Metro is in service, what facilities are proposed for the monthly ticket?<br>Q13-2. Fare discount for local person of the Patna.<br>Q14. Provision of underground parking<br>Q15. Emergency actions in the event of an earthquake while the metro is in operation<br>Q16. To hope it will be completed soon<br>(Opinion)<br>Expectations for employment through this project<br>The Metro is a safe means of transportation for women and helpful for the tourist.<br>The Metro will enhance the business opportunity and connectivity.<br>**<Sections where construction has already started>**<br>Q17-1. Dust pollution caused by material transport trucks is severe.<br>Q17-2. The entry and exit of Hydraulic and overtaking by construction vehicles cause traffic jam.<br>Q17-3. Part of the road is occupied by PMRC and there is no parking space.<br>Q17-4. There is no proper traffic management by PMRC, and no proper maintenance.<br>Q18. This construction work is too slow. |
| Reply from PMRCL | A1. Mostly the path will be above road and underground, and it will provide many benefits like employment, connectivity etc. However, if any adverse impact done by metro, appropriate action will be taken on it.<br>A2. PMRC Office in Indra Bhawan where you can place your complain<br>A3. The tentative time line is for 2025.<br>A4. The Environment development program will be continued as going on.<br>A5. There will also same kind of plantation will be developed.<br>A6. Once finalized, the government will be notified and the owner will be informed.<br>A7. If any obstruction will faced then it will be shifted properly.<br>A8. 20-30 meter. It may be very depending on the design.<br>A9. Provision in Metro project that on the basis of their capability and skills people get the employment.<br>A10. Appropriate measures will be taken to ensure that the store is not inconvenienced.<br>A11. Whatever done by the Patna Metro is advertised through the newspaper and different mediums on time to time.<br>A12. The application will be published in the newspaper as an open tender for everyone.<br>A13. Till now nothing has been decided but definitely your suggestion will be considered.<br>A14. Installation of the parking lot depends on location.<br>A15. The Metro is using the earthquake resistance technique. If such situation happens, the metro will stop at its location.<br>A16. The work is completed within the defined framework as soon as possible.<br>**<Sections where construction has already started>**<br>A17. Appropriate action will be taken on it by conveying the same to the relevant authority and department<br>A18. The work will be done in fast-forward mode. |

Source: JST




Source: JST

**Figure 16-2: PC Photos of 2nd PC**

### 16.2.2 SIA

#### (1) Background

On behalf of State of Bihar, Patna District Administration, Office of the Collector (Land) is responsible for implementing the land acquisition process, including the SIA study and the Public Hearing. The State public hearing for the Project has started in 2021.

PMRCL explained that the District Administration is implementing public hearings following the legal requirements of India, which reflects the findings of SIA surveys undertaken by the Bihar State. JST followed up the public hearings by the District Administration, so that they do not deviate from the JICA

Guidelines'' requirements for stakeholder meetings. Therefore, the public hearings by the District Administration qualifies as the second stakeholder meeting required by the JICA Guidelines

### (2) Date, Location, Number of Attendants

District Administration hired SIA experts and the experts implemented SIA surveys including identification of registered landowners as well as of self-claimed landowners. In Public Hearings, all identified landowners were invited, but anybody who are interested in the Project and land acquisition could attend freely. The meetings were started with reading the summary of the draft SIA report including the findings of the surveys of the project objectives, land registration, and socio-economic status of the landowner PAHs.

The location of the public hearings was proposed by the SIA experts and decided by the District Administration. Locations such as meeting rooms of official institution, halls at ceremonial facilities, and shop fronts of the affected structures were selected for the convenience of the attending PAHs.

As a result, almost all attendants were male attendants. The reasons of the distorted gender balance can be understood as a mixture of the followings.

- The District Administration invites representatives of PAHs to the Hearing, and the PAHs naturally send a male representative reflecting male-dominant mindset that is common in Bihar.
- The 2013 Land Acquisition Act does not mandate measures for gender-balanced participation.
- In the interview surveys for EIA and SIA in this report, many female interviewees hesitated expressing their opinions or giving their names to the interviewer, who were also female Indian surveyors. The surveyors felt that majority of female population in Patna are comfortable with following male instructions, and are not used to following their individual interests or instincts when they chose their action, including attending the Public Hearing.

**Table 16-7: Locations, Date, and Number of Attendants of the Public Hearing**

| | Corr | Location | Town | Venue | Date | Number of Attendants | Attendees |
|---|---|---|---|---|---|---|---|
| 1 | 2 | Depot Area | Pahadi, Ranipur | Patliputra Bus Complex, Pahari, Patna | 2021.June 4 | About 250 (Female 0) | Directly and indirectly affected people, Representative of minority groups (i.e. Muslims (Waqf Board)) Public representatives (representative of ward members), Representatives of PMRCL, SIA experts |
| 2 | 2 | New ISBT Sta. | Pahari | District Administration Office | 2021.Aug.14 | 15 (Female 0) | |
| 3 | 2 | Akashvani Sta. University Sta. | Moharrampur, Sandalpur | Hotel Rajasthan Bihar State Sunni Waqf Board | 2022.Feb.17, 2022.Feb.23 | 12 (Female 0) | |
| 4 | 1 | Jaganpura Sta. Ramakrishna Nagar Sta. Mithapur Viaduct | Jaganpura, Changad, Bigrahpur | Maa Kamla Utsav Hall | 2022.May.28 | 35 (Female 2) | |
| 5 | 1 | Rajabazar Sta. Rukanpura Sta. Patna Junction Sta. | Salempur, Sadikpur, Moharrampur | Patna Municipal Corporation Office | 2022.Aug.20 | 40 (Female 1) | |
| 6 | 2 | PMCH Sta. | Muhharampur | At the affected shops | 2022.Sep.5 2022.Sep.9 | 22 (Female 0) | |

Source: JST based on the State SIA Reports





Depot Area Public Hearing (2021.June 4)



New ISBT Sta. Public Hearing (2021.Aug.14) (Attendants refused to sign and to be photographed)





Jaganpura Sta., Ramakrishna Nagar Sta., Mithapur Viaduct Public Hearing (2022.May.28)





Rajabazar Sta., Rukanpura Sta., Patna Junction Sta. Public Hearing (2022.Aug.20)



PMCH Sta. Meeting with PAHs (2022.Sep.09)

Source: JST based on the State SIA Reports

**Figure 16-3: Photo Records of Public Hearing by District Administration**

In the State SIA survey, the SIA experts visited registered landowners and self-claimed land owners to disseminate the information about the Project, and to collect information of their socio-economic conditions and perception about the Project. The results of Interview Survey was summarized in 15.5.2 Profile of Project Affected Landowners.

Focus Group Discussions were held in the affected area to repeat the information dissemination, to understand collective opinions of the PAHs, including the landowners, tenants, and other PAHs, and to invite them to the Public Hearings.





SIA Interview Survey at the Depot area (2021 Feb.)





Focus Group Discussions at the Depot area (2021.Mar.03, 2021.Mar.05)

| | |
|---|---|
|  |  |
| SIA Interview Survey at Akashvani and University Stations (2021 Feb.) | |
|  |  |
| Focus Group Discussions at at Akashvani and University Stations (2021.Feb.) | Focus Group Discussions at Ramakrishna Nagar St. (2022 Apr.12) |
|  |   |
| Focus Group Discussions at Mithapur Viaduct (2022 Apr. 14) | Focus Group Discussions at Mithapur Viaduct (2022 Apr. 15) |
|  |  |
| SIA Interview Survey at Raja bazar Sta., Rukanpura Sta., Patna Junction Sta. area (2022 June) | Informal Discussions at Patna Junction Sta. area with PMRCL staff (2022 June) |

| | |
|---|---|
|  |  |
| SIA Interview Survey at PMCH Sta. area (2022 Sep.) | SIA Interview Survey at PMCH Sta. area (Bihar State Sunni Waqf Board Chairman) (2022 Sep.) |

Source: JST based on the State SIA Reports

**Figure 16-4: Photo Records of Interview Survey and Focus Group Discussion**

### (3) Records of Communications

Records of opinions and responses taken from the State SIA reports are explained in the following tables.

At most of the locations, the attendants made proposals of moving the Project sites to some other places a few kilometers away. Since the Patna Metro is a linear infrastructure, and it is not feasible to move parts by parts on locations distant from the designed corridors, such proposals were listened to, but were rejected.

Many attendants required that the impact on their land must be minimized. On this point, PMRCL promised that the significance of the impact will be explained in detail, and will be minimized.

Concerns were expressed by business owners about their losing entrance/exit to their land during construction or after the construction. On this point, PMRCL assured to secure adequate entrance and exit in both construction and operation phase.

It was found that the PAHs are demanding the communication with the District and PMRCL. The District and PMRCL need to meet the PAHs in separate, individual manner to explain the significance of the Project impact, as well as to listen to unique conditions each PAH has.

The Land Acquisition Act 2013 requires multiple timing of meetings between the stakeholders, as listed below. PMRCL, cooperating with the District Administration, must continue communication with the stakeholders to reach a mutual and feasible agreement between the parties.

1) during the site measurement activities after the publication of the Preliminary Notice (Art. 11 Notice);
2) during the object filing phase about taking of the land, in 60 days after the publication of the Preliminary Notice;
3) during the public hearing on the draft State Rehabilitation and Resettlement scheme, based on the PMRCL policy; and
4) during object filing phase about the value of the compensation after the publication of the Article 19 Notice.
5) throughout the Project life through the Grievance Redress process.

**Table 16-8: Opinions Presented in the State Public Hearing: Depot Area (Report 1)**

| | Opinions | Responses |
|---|---|---|
| 1. | Acquisition of areas other than the area of the proposed area must be considered.<br>The acquisition can be done 500-600 meters south from the present alignment, in which no house is built, owned by the land of Sahara India, which has to sell its land.<br>Also, there is a common land along the north road of the bypass police station.<br>If these options are considered, then the compensation revenue for this project is likely to cost the government comparatively less. | The proposed location has been selected as most suitable by engineering design perspective. |
| 2. | If the acquisition process is done 2 km away from this site, then less number of people will be affected and the government will also get the benefit of revenue. | |
| 3. | The land of Pahari Circle has been acquired four times before this under National Highway Scheme, Transport Nagar Yojana, Ganga Pollution Scheme and Patliputra Bus Complex Scheme.<br>There should be no more land acquisition in this area. | Locating the suburb of the Patna Metro area, many infrastructure projects are implemented in this area. |
| 4. | Many house construction committees are working on the land falling under the present proposed acquisition. Due to this about 1300 members who have bought small pieces of land for house construction are to be affected. Some people have already done house building work. | All project-affected persons will be compensated for their loss. |
| 5. | All the land to be acquired under one project should be at one rate for Circle Pahari and Circle Ranipur.<br>Compensation should be paid at market rate. | Compensation will be paid at market rate, based on the survey results done by licensed surveyor, commissioned by the District Administration. |
| 6. | Give a job in Patna Metro Corporation for affected family. | Rehabilitation measures will include the provision of priority in governmental recruitment. |
| 7. | After the construction of malls and multiplexes by bus complex and metro, the local people will have to face serious problems related to traffic and pollution. | The planned malls and bus complex will have adequate parking spaces separated from the road. Road traffic will move smoothly by construction of the Metro. |

Source: JST based on SOCIAL IMPACT ASSESSMENT STUDY LAND ACQUISITION FOR PATNA METRO RAIL MULTI PURPOSE DEPOT CONSTRUCTION REGION-PATNA CITY, DISTRICT-PATNA

**Table 16-9: Opinions Presented in the State Public Hearing: New ISBT Sta. Area (Report 2)**

| | Opinions | Responses |
|---|---|---|
| 1. | Leaving the due proposed acquisition, land should be acquired at 500 meter away (Badsahinala) to reduce the crowd of Metro station and ISBT. If this is not possible then other options may also be considered.<br>Compensation for all the land to be acquired under project should be at market rate.<br>Get a job in Patna Metro Corporation. | Due to site constraint, it is not feasible<br>The request will be considered as per Entitlement matrix and qualification. |
| 2. | It was told by the local people that many house construction committees are working on the land falling under the present proposed acquisition.<br>Due to which about 60 members who have bought small pieces of land for house construction are getting affected. Some people have done house building work.<br>If the acquisition process is done 1 km away from this site, then less number of people will be affected and the government will also get the benefit of revenue. | Due to site constraint, moving the Project site is not feasible.<br>All project affected persons will be compensated for their loss. |
| 3. | The local people also told that in future after the construction of malls and multiplexes by bus complex and metro, the local people will have to face serious problems related to traffic and pollution. For this reason also people do not agree with this acquisition.<br>Hence, the proposed acquisition process should be done only after considering the options given by them. | The planned malls and bus complex will have adequate parking spaces separated from the road. Road traffic will move smoothly by construction of the Metro. |

Source: JST based on Social Impact Assessment Study due to Proposed Land Acquisition for Multipurpose Metro Parking and Station Project, District-Patna, Draft Report

**Table 16-10: Opinions Presented in the State Public Hearing: University Sta. and Akashvani Sta. Area (Report 3)**

| | Opinions | Responses |
|---|---|---|
| 1. | The area of proposed acquisition is near both Patna Junction and AIR station, which can also be covered on foot, except other routes should be acquired.<br>Patna Metro is not that suitable for Dak Bungalow area.<br>If this is not possible, then other options should also be taken into consideration. If it is necessary to take the Metro path, then it should be taken through SP Verma Road or Exhibition Road, if required. | The locations of Patna Metro facilities are designed to maximize the convenience of customers who travel between different modes of transportation. |
| 2. | Due to the blockage of the traffic route during the progress of the work, there will be a huge reduction in the activities of the general public.<br>Due to which the entire business process of Fraser Road will come to an end. Due to which the maintenance of the families of the working workers of those related commercial establishments will be affected. Whose number is in the thousands?<br>Along with this, due to the stagnation of business, the revenue income of the government will also decrease. | All measures will be taken to minimize impact on existing businesses and commercial activities during the construction stage.<br>Loss of business income during the construction stage shall be assessed and negotiated against the Land Acquisition Act, 2013. |
| 3. | There should be no effect on the entry and exit of the commercial establishment during the construction work. | |
| 4. | The land which is the property of the Waqf is the land donated. If possible, take this project from the other side. If there is no option, pay attention to the points below.<br>➢ The construction related works should be done while maintaining the existing green area.<br>➢ If possible, allotment of land should be done in lieu of land.<br>➢ After the completion of the work, the damaged boundary wall (hostel) and the premises should be constructed as soon as possible according to the before-construction condition.<br>➢ The compensation for the land acquired under the project should be paid at the market rate and not through the MVR. | Due to site constraint, selecting other land plot instead is not feasible.<br>Compensation will be made by cash as per Entitlement matrix.<br>At the completion of the work, boundary walls will be re-installed before handing over the site to the original owners. |

Source: JST based on Social Impact Assessment Study due to Proposed land acquisition for University and Akashvani metro station project, District-Patna draft report

**Table 16-11: Opinions Presented in the State Public Hearing: Jaganpura Sta., Ramakrishnanagar Sta., and Mithapur Viaduct Area (Report 4)**

| | Opinions | Responses |
|---|---|---|
| 1. | The owner of the Kamla Utsav Hall informed us to consider an alternative alignment as the government land is available on the opposite side of the proposed alignment.<br>The person (Mr. Sunil Kumar) who is running the Kamla Utsav Hall has invested Rs. 3 crore since 2016 to develop that Hall, however due to Covid lockdown situation he has not recovered his investment yet and there will be huge loos to him as well as people dependent on the Hall for their livelihood.<br>As there is no clarity on which portion from plot number 30 is to be acquired and since more than 50 families are residing in that plot and their livelihood depends on that plot in terms of business establishment, the landowner begged to consider alternative alignment. | Due to site constraint, it is not feasible to move the Project site<br>All project affected businesses, households and families will be compensated for their loss against the Land Acquisition Act, 2013. |
| 2. | Most of the landowners have a small business and they put a lot of effort to develop their business which also provides a livelihood for other indirect stakeholders, (a list of indirect people may be impacted is provided in the appendix) hence they were against the current acquisition and begged to consider an alternative alignment at Mithapur Bypass under Bigrahapur Circle. | |
| 3. | One landowner Madhuri Devi having small children depend on a shop near Mithapur Bypass was very much worried and pleaded to consider an alternative alignment from Bigrahpur Circle. | Impacts on individual household will be communicated soon separately, and every possible effort will be made to minimize your loss. |
| 4. | A few owners of the plot were not living permanently and tenants are staying in the | Compensation for the land as well as the investment made by the tenants |

| | Opinions | Responses |
|---|---|---|
| | house on rent.<br>One family belonging to Dineswar A. Pandey staying on the current land for more than 50 years and a few of his family members are engaged in some private jobs, they had a plan to build some commercial/residential structures on the existing vacate land falls under current acquisition.<br>However, they didn't oppose the acquisition and informed that they will get benefit from this metro project in terms of easy transportation and new business opportunities will also be generated.<br>During the discussion with landowners also revealed that they pay a good amount of tax to the municipality therefore they are expecting to get a good compensation package in terms of the valuation of their land | will be made against the Land Acquisition Act, 2013. |

Source: JST based on Social Impact Assessment (SIA) of land acquisition in Patna district for the construction of Jaganpura metro station, Mithapur metro station, and Ramkrishanagar metro station.

## Table 16-12: Opinions Presented in the State Public Hearing: Rukanpura Sta., Rajabazar Sta. and Patna Sta. Areas (Report 5)

| | Opinions | Responses |
|---|---|---|
| 1. | Ankit Sanaf, Puran Chandra Sarraf claimed that just they abolished their building to make a multistory mall for medicine. They are under debt of INR. 85,000,000 and running interest over it. They want appropriate compensation of four times of MVR.<br>They also requested to shift the project on its adjacent plot. | Due to site constraint, shifting the Project facility is not feasible.<br>Impacts on individual land plot will be communicated soon separately, and every possible effort will be made to minimize your loss. |
| 2. | Dr. A Hai, at PARAS-HMRI Hospital, made a request to shift the proposed metro project site westward of Paras HMRI Hospital to the adjacent available government land. Being reputed hospital in Bihar, around 450,000 of Out Patient Department Patient are consulted and operated around 100,000 patients yearly.<br>According to the physical verification and demarcation sign. Total front land of the PARAS HMARI is going to be acquired. Need serious attention in this regard. | The government has been informed about the concern about the hospital access; the PMCH station is located underground, and the station facilities are located so that the existing hospital access will not be affected. |
| 3. | Rajesh Kumar, associated with Tirupati Auto (related with Plot 754, 752) claimed that once acquisition in present form will be completed, complete entrance of the workshop will be blocked. The acquisition may be structured in a way to assure their entrance (in/out) for commercial purposes.<br>According to Digambar Kumar Verma, Amin related with Metro, reported that Plot 752 also be acquired but it was not mentioned in the list of affected land provided by the District Land Administration Office, Patna. | Impacts on individual land plot will be communicated soon separately, and every possible effort will be made to minimize your loss.<br>All measures will be taken to minimize impact on existing businesses and commercial activities during the construction and operation stage. |
| 4. | Binod Kumar Bhaturia, related with Khasra 87, 89 and 90, reported that the said land is under litigation with Government itself and amalgamated and matter is pending in Hon'ble Patna High Court, so they said that first Government should handover the land then, acquisition may be taken place accordingly. | The government has been informed about the litigation; the matter is to be solved in the acquisition process as suggested. |
| 5. | Suryanarayan Yadav, related to Plot 763 and 765, said that land may not be acquired more than one (1) meter from Bailey Road, because there is already Septic Tank and sewerage system. So the present form of acquisition may be avoided. | Impacts on individual land plot will be communicated soon separately, and every possible effort will be made to minimize your loss. |
| 6. | Saurabh Narayan Singh said that due to proposed land acquisition there will be land lock situation and depreciate the values for remaining land. He may suffer huge economic and financial loss. He demanded revised MVR according to market situation at present value. | All these things will be deeply considered. |

Source: JST based on Social Impact Assessment of Land Acquisition for Patna Metro, Patna.

**Table 16-13: Opinions Presented in the State Public Hearing: PMCH Station Area (Report 6)**

| | Opinions | Responses |
|---|---|---|
| 1. | Compensation for all the land acquired under the project should be at the market rate. | Compensation for the land as well as the investment made by the tenants will be made against the Land Acquisition Act, 2013. |
| 2. | The PAP may be preferred for employment in Patna Metro. | The request will be considered as per Entitlement matrix and qualification. |
| 3. | Land should be acquired at 50 meters away (west, Anjuman Islamia) or 1-15 meters east.<br>If this is not possible, then other options may also be considered. | Due to site constraint, shifting the Project facility is not feasible.<br>Impacts on individual land plot will be communicated soon separately, and every possible effort will be made to minimize your loss. |
| 4. | To help people in business whose small shops are likely to be affected completely, to help them with the necessary land and capital for setting up the business. | Compensation will be made against the Land Acquisition Act, 2013 and the Entitlement Matrix. |
| 5. | The classification of land should be met with a proper compensation in the context of present use. | Compensation for land will be made against the Land Acquisition Act, 2013. |

Source: JST based on Social Impact Study, Draft Report of SIA Study of Proposed Patna Medical College Hospital Metro Station, Revenue Village-Muhharampur, District – Patna

# 17. Detailed Project Cost Estimates (N/A)

# 18. Transit Oriented Development (TOD) Plan

## 18.1 Overview of Existing Studies

The National Transit Oriented Development (TOD) Policy issued by the Government of India provides guidelines for Land Value Capture (LVC) associated with transit projects. The area within walking distance (500m to 800m) from railways and stations will receive benefits such as value increases due to the development of public transportation, and is the target area for LVC. Then, within the area, by increasing the density and multi-purpose land use through additional floor area ratio (FAR), external development charges (EDC), land use changes, etc., The tax revenue generated by the project and the profit from the sale of land with high-added value will be appropriated for project financial resources and operation and maintenance costs. In addition, in 2021, IRSDC (Indian Railway Station Development Corporation) published the Guidebook for operationalizing National TOD policy for Railway (Re)development, 2021. This guidebook is intended to be used by authorities, developers, engineers, etc. And this guidebook provides design guidelines for access, flow of people, land usage plans, public spaces and parking lots, etc.

The calculation of LVC apply the National TOD policy issued by the Government of India. This National TOD policy provides examples of Land Value Capture (LVC) methods used in India. provides examples of Land Value Capture (LVC) methods. Each state and major city has established its own TOD policies based on this and is promoting public transportation projects. The LVC methods of sale of additional FAR, external development charge, and change of land usage in TOD zone. The case of Lucknow Metro, which is similar to Patna Metro is considered as a benchmark data. The assumption of calculation of LVC is shown in Table 18-1.

FAR standard is not uniformly determined by area, etc., but varies depending on conditions such as the width of the road facing the building, the ratio of the area of the building in the site, and the planned height of the building etc.

**Table 18-1: Assumption for estimating LVC**

| Items | Assumption for estimating |
|---|---|
| Premium on additional FAR | • Sale of FAR area is based on the National TOD policy. The possibility for the area for sailing is estimated as 50 % of the TOD zone.<br>• Rate of additional FRA is Rs. 4,000/sqm.<br>• Percentage of the sales is estimated considering other metro projects. |
| External Development Charges | • The area for external development charge is assumed to be same as of the TOD area.<br>• The external development charges are assumed to be 15 % of the rate of additional FAR. |
| Change in land use | • The area for change in land use is assumed to be 5 % of TOD area.<br>• The fee for charge is considered to be 50 % of the purchase of additional FAR. |

Source: JST

In PMRCL, by applying the above methods, revenue is estimated by treating LVC as an item of TOD income (Table 18-2). It is proposed that 35% of the yearly projected revenue collection from LVC will allocate to Patna Metro.

**Table 18-2: Estimated Revenue from TOD (In Rs.Crore)**

| Items | Total Revenue | | | |
|---|---|---|---|---|
| | 202-25 | 2031-32 | 2041-42 | 2051-52 |
| Premium on Additional FAR | 60.2 | 84.8 | 138.1 | 224.9 |
| External Development Charges | 90.4 | 127.2 | 207.1 | 337.4 |
| Change in Land use | 42.2 | 59.3 | 96.7 | 157.4 |
| **Total** | **192.8** | **271.3** | **441.8** | **719.7** |

Source: DPR Table 0.26

What Japanese private railway companies refer to as TOD revenue is a property development revenue in PMRCL.

JICA Survey Team conducted the Detailed Project Report (DPR) analysis, field surveys, and interviews with PMRCL for the property development around the corridors (Table 18-3, Table 18-4, Figure 18-1, Figure 18-2).

**Table 18-3: Development Status around Metro Stations (Corridor 1)**

| No. | Station Name | Development Status |
|---|---|---|
| 1 | Danapur | • Many military facilities and lodgings are located.<br>• Land Use Plan Classification:Residentail area |
| 2 | Saguna Mor | • This area is one of the candidates for property development.<br>• Many real estate developments are on-going. The condo, and apartment around this area is targeted for people categorized as upper-middle class. Average wage of the upper-middle class is over 150,000 Rs./month.<br>• Local markets and auto rickshaws are gathering around the site of planned Saguna More Sta., where is the transport hub.<br>• Land Use Plan Classification:Residential area |
| 3 | R.P.S. Mor | |
| 4 | Patliputra | |
| 5 | Rukanpura | • Residential area<br>• PMRCL has a plan to acquire land adjacent to the station (approx. 1,400 spm) and develop for the business.<br>• Land Use Plan Classification:Residential/commercial area |
| 6 | Raja Bazar | • Large hospital is located in the front of the planned station site.<br>• The residential area for people categorized middle class. Average wage of middle class is around 50,000 - 60,000 Rs/month.<br>• Enter the underground section from this area.<br>• Land Use Plan Classification:Residential area |
| 7 | Patna Zoo | • Planned station site is located in the front of Patna Zoo.<br>• There are government officials' residences, and facilities.<br>• Orderly area<br>• Land Use Plan Classification:Residentail/public area |
| 8 | Vikas Bhawan | • Many government offices are located around the stations.<br>• Land Use Plan Classification:Commercial/public area |
| 9 | Vidyut Bhawan | |
| 10 | Patna Junction | • Re-development of the station square in front of Patna Junction Sta. is planned.<br>• PMRCL has a plan to a land adjust to the station. But the budget and business plans are not confirmed yet.<br>• Land Use Plan Classification:Commercial/public area |
| 11 | Mithapur | • Ex-Bus terminal is located in the front of the station.<br>• Patna City plans to invite a school there.<br>• Land Use Plan Classification:Residential area |

| No. | Station Name | Development Status |
|---|---|---|
| 12 | Ramkrishna Nagar | • Newly developed residential area.<br>• Land Use Plan Classification:Residential area |
| 13 | Jaganpura | • Unauthorized local fish market is located<br>• Land Use Plan Classification:Residential area |
| 14 | Khemni Chak | • Common station for Corridor 1 and 2<br>• Land Use Plan Classification:Residential area |

Source: JST



(2) Rickshaws are gathering



(3) Property development near metro lines



(6) Parking spaces under viaduct



(11) Ex-Bus terminal

Source: JST

**Figure 18-1: Survey of TOD around Stations (Corridor 1)**

**Table 18-4: Development Status along Metro Stations (Corridor 2)**

| No. | Station | Development Plan/Status |
|---|---|---|
| 1 | Patna Junction | • Common station for Corridor 1 and 2<br>• Connecting station to Patna Junction Station of Indian Railways<br>• Land Use Plan Classification:Commercial/public area |
| 2 | Akashuvani | • Commercial area of Patna city. Shopping malls are located around the station<br>• Land Use Plan Classification:Commercial area |
| 3 | Gandhi Maidan | • Planned station site is located in the front of park<br>• Vendors and Rickshaw are gathering for people coming to the park<br>• Land Use Plan Classification:Commercial/public area |
| 4 | PMCH | • Residences and commercial area<br>• Land Use Plan Classification:Commercial/public area |
| 5 | University | • Several universities and schools are located<br>• This area is center of old city<br>• Land Use Plan Classification:Commercial/public area |
| 6 | Moin Ul Haq | • Planned station site is in the front of the public stadium.<br>• Renovation of stadium is planned, and the tender has been done.<br>• Land Use Plan Classification:Commercial/public area |
| 7 | Rajendra Nagar | • Connecting to the station of Indian Railways<br>• Land Use Plan Classification:Commercial/public area |
| 8 | Malahi Pakri | • Parking lots are planned at public site (1,250 sqm)<br>• Residential area. It is seemed that local residents are against the project.<br>• Construction is on-ongoing in the middle of a narrow road, where surrounded by local residents. The atmosphere is bad. Construction in the middle of a narrow road<br>• Land Use Plan Classification:Residential area |
| 9 | Khemni Chak | • The construction is on-going along the large road.<br>• Land Use Plan Classification:Residential area |
| 10 | Bhootnath | |
| 11 | Zero Mile | • Residential area along the large road<br>• Land Use Plan Classification:Residential area |
| 12 | New ISBT | • New bus terminal is under construction.<br>• Parking lots are planned at the private site (8,229.37 sqm)<br>• PMRCL plans to acquire a land (11.3 Ha) adjacent to the depot and develop real estate, and is discussing funding and business plans with private developers.<br>• Land Use Plan Classification:Residential area |

Source: DPR and JST

| | |
|---|---|
|  |  |
| (9) (10) along the metro corridors | (12) New bus terminal at New ISBT |

Source: JST

**Figure 18-2: Survey of TOD around Stations (Corridor 2)**

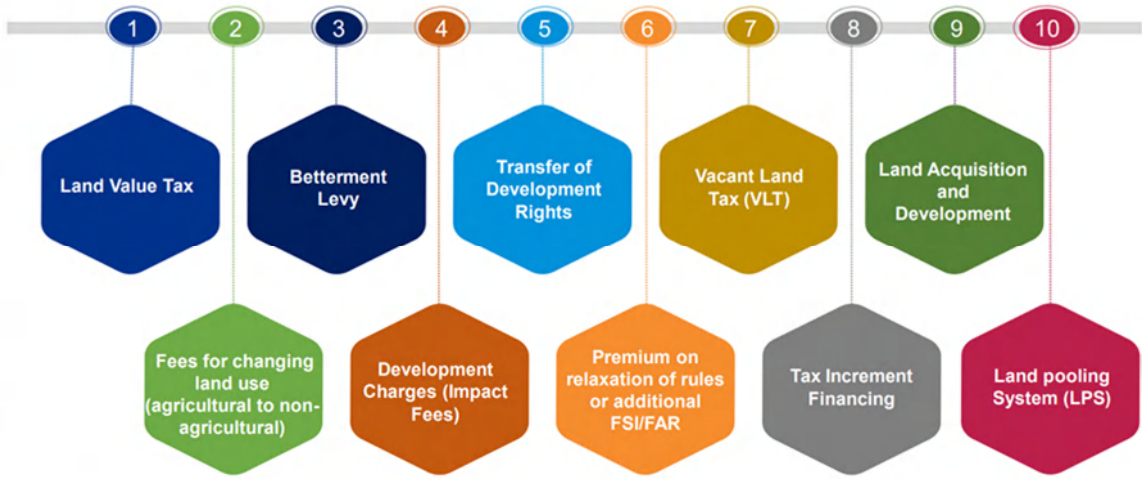
## 18.2 Reviews of Existing Studies and Proposals for Improvement

Though PMRCL plans in the DPR to apply 35% of yearly projected revenue collected from LVC to O&M expenditure,.there is no clear analysis of its validity. Patna City and PMRCL should plan a concrete introduction scheme.

In Japan, the word TOD is used in a broad sense, such as retail in the station area, property development of railway companies for non-fare box revenue, transit-oriented development for public transport-friendly city, and development of station square as a transit hub. However, PMRCL classifies the revenue from the land value capture (LVC), which is the scheme to apply the profits such as land price increases along the metro corridors due to the project to the construction or O&M expenditure, as TOD revenue on account, and revenue from the property development is classified as property development revenue on account.

The national TOD policy issued in 2015 by the Government of India has introduced various methods of Land Value Capture (LVC) in Inada and overseas (Figure 18-3). The introduction LVC is a method that has been attracting attention in recent years as one of the means of generating financing for the development of large public projects (Table 18-5)

There are divided into two major LVC methods: (1) those based on taxes and fees (land/property taxes, beneficiary fees, etc.) and (2) those based on development (sales/leasing of government-owned properties, etc.). Each method is not new, but it is characterized that it is summarized under one concept as a method of financing for public works projects.




Source: Ministry of Housing and Urban Affairs, the Government of India

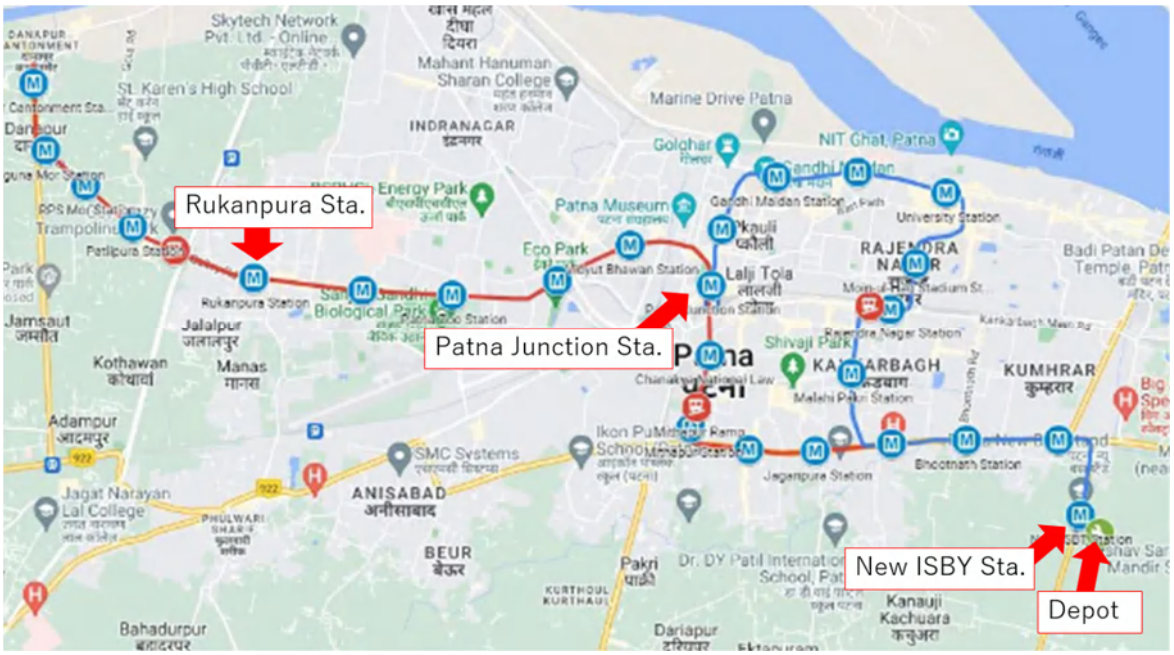
**Figure 18-3: Methods of Land Value Capture (LVC) applied to metro projects**

**Table 18-5: Examples of Land Value Capture (LVC)**

| No. | City (Country) | Scheme |
|---|---|---|
| 1 | Delhi, India | • LVC is applied to the development along railway lines by the initiative of the Government of India.<br>• Delhi Metro received the land transfers from several government agencies, and sells or leases development rights for supplementing the revenue. |
| 2 | Hyderabad, India | • Public Private Partnership (PPP) scheme is applied for Hyderabad metro<br>• The successful bidder is given the rights to operate the metro and to develop properties along the lines.<br>• The city has set a 300 m width along the lines as a TOD area. Property development project such as offices, residences, and the stations integrated with commercial facilities are progressing. |
| 3 | Kochi Metro | • Kochi Metro has agreed to receive the transfer of the city-owned land before the extension of Phase 2, and is in the process of transferring. On the transferred land. Kochi Metro plans to build a high-quality residential complex (Metro City Project) targeting the middle class families, and to apply the revenue from the project to O&M expenses. Kochi Metro plans to raise Rs. 10 Lak funding. |
| 4 | Pune Metro | • Maha Metro, the operator of Pune Metro plans to build a commercial building at Swargate Sta., which will be leased by the city for the non-fare box revenue. Maha metro plans to build a shopping complex there. The city increased the floor area ration (FAR) for the project. The city has decided to take 50 % of the profits from the business and use it to cover the cost of the metro project. |
| 5 | Hong Kong, China | • The Government of Hong Kong owns all land in the territory.<br>• The government exclusively grants Hong Kong MTR the rights to develop the land above and around the new stations at a low price, assuming that the stations does not exist.<br>• Hong Kong MTR develops, sells, leases the land based on the market value assuming that the new line exists.<br>• Income from this business will be used to supplement project costs, O&M expenditure. |
| 6 | Nanchang, China | • Regional municipalities have a responsibility for city-level land use planning and regional infrastructure services in China.<br>• Nanchang city established a railway company, Nanchang Railway Transit Group (NRTG).<br>• The city acquired the land development rights and lease rights after the release of the city master plan and land use plan.<br>• The city raised the FAR (upper limit of floor area ratio) of the acquired land properties.<br>• NRTG invest the properties directly, sells development rights to the private sectors etc.<br>• The city and NRTG sell the owned properties through auction or lease them after metro starting operation, and compensate the income to the project and O&M expenditures |

| No. | City (Country) | Scheme |
|---|---|---|
| 7 | Sao Paulo, Brazil | • The city owns little properties available for development.<br>• The city sets the basic floor area ration (FAR) at 100 – 299 %. The city securitize the air rights using FAR transfer scheme. And the air rights are traded on the Sao Paulo Stock Exchange.<br>• If the developer build in excess of FAR of the property, the developer should buy a securitized certification for the additional FAR.<br>• The securities are traded on the Sao Paulo Stock Exchange. The income become the urban development fund (Fundo de Desenvolvimento Urbano) of the city, and is used as financial resources for the project of metro and monorails etc. |
| 8 | Portland, USA | • As a project financial resource for the urban railway of Metropolitan Area Express (MAX) extension work, the city applied the tax increment financing method which is raised directly or as collateral to issue bonds to procure infrastructure investment funds. |
| 9 | Washington D.C, USA | • Washington Metropolitan Area Transportation Authority (WMATA) applied a joint development program which is a scheme to develop properties together with private sectors and landowners.<br>• The private sectors and landowners are provided the development rights for constructing residential or commercial buildings above or in the public owned land, instead of offering air rights, land leasing, connection fee to stations, and operation cost. |
| 10 | London, UK | • The City of London will invest more than £55,000 in non-residential facilities in the City of London area to finance the Cross Rail project (£14.8bn), a 118km rail link between Heathrow Airport and the West End of the city center. Taxed at 2 pence per pound.<br>• For this project, 40% of the funds will be procured from LVC |

Source: JTTRI, Case study of LVC of the world biggest cities, JST



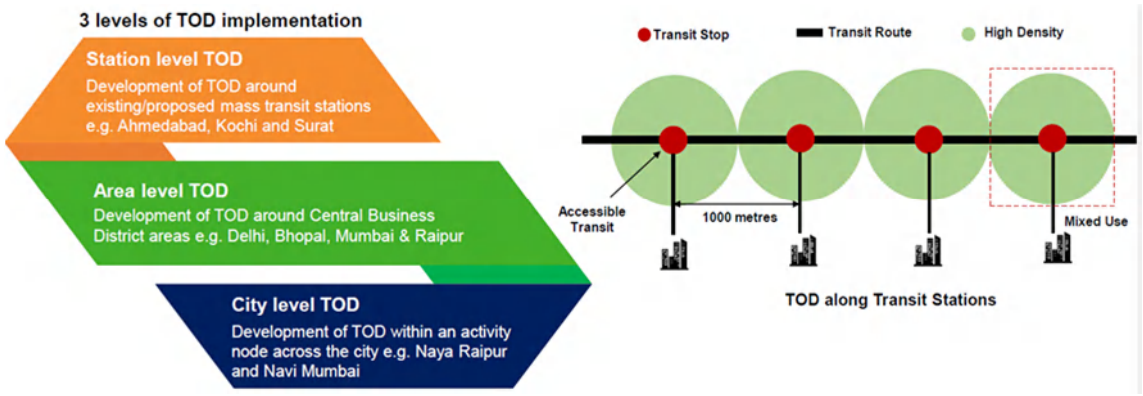

Source:JST

**Figure 18-4: Planned property development sites of PMRCL**

At the time of the JICA Team's survey, PMRCL has a plan to acquire and develop privately owned property adjacent to ICTB depot. In addition, PMRCL has similar plans for property development at Rukanpura Sta. and Patna Junction Sta. However, the financing and development plans have not been decided yet.

On the other hand, there are many possibilities for transit-oriented development for city planning rather than commercial purposes. The National TOD policy clarifies TOD into (1) development at the station level, (2)

development at the area level centering on the station, and (3) urban development at the city level (Figure 18-5).




Source: Ministry of Housing and Urban Affairs, the Government of India

**Figure 18-5: Categorization of TOD in National TOD Policy**

Regarding the development of (1) station level and (2) station area, the redevelopment of the station square of Patna Junction Station, which is a transportation hub between the Indian Railways and the Patna Metro, and the redevelopment of the city center by relocating universities and schools to the suburbs, and supply of high-quality housing for middle- and low-income people in cooperation with the private sector or housing supply public corporations, etc. for the city level development (3) can be considered.

PMRCL is a public authority and does not own land for profit business for real estate development. Consensus building among stakeholders will be required for the development of the profit business. On the other hand, in terms of urban development using public transportation and the development of transportation hubs, collaboration with Patna City and others seems to have great potential. With the Patna Metro as the axis of public transportation, the city of Patna will be developed in a public transportation-oriented city. As a result, the number of passengers on the Patna Metro can be increased, which will lead to the expansion of earnings of non-fare box businesses.

## 18.3 TOD in Japan

From the field survey of JST, PMRCL can refer to the experience in promoting both railway construction and housing development during Japan's period of high economic growth, and the special law which was enacted to make possible to combine railway construction and housing development at same time when constructing Tsukuba Express (TX) in recent years.

In Japan, the word of TOD is used in a broad sense, such as retail business in stations, urban development along rail lines, transit-oriented development, and development of a station square as a transportation hub.

Since PMRCL is a public authority, there are limits to the business development of retails in stations and property development as a profitable business. On the other hand, in terms of urban development along the corridors and redevelopment of station square, in collaboration with Patna city and other relevant authorities, there are great potential for development. Patna city can be developed as a public transport-friendly city with the metro as a core of public transportation. As a result, an increase of metro passengers can be expected,

and which will lead to an increase of non-fare box revenue as well.

From the field survey of JICA Team, PMRCL can refer the Japanese experiences in promoting both railway construction and housing development during the population growth period and the Tsukuba Express (TX) in recent years. For the TX project, a special law was enacted for railway construction and housing development efficiently at the same time.

During Japan's high-economic growth period from the 1960s, the problem of housing shortages arose due to the concentration of the population in urban areas. For this reason, the government developed large-scale housing complexes in the suburbs to supply a large amount of housing, and also enacted legislation to integrate railway development and development along railway lines.

The Act on Special Measures Concerning the Integrated Promotion of Housing Land Development and Railway Development in Large Urban Areas (Act on Special Measures concerning Comprehensive Advancement of Housing Development) aims to promote railway projects by integrally carrying out urban development along railway corridors and integrated railway development. It is a law aimed at the development of residential land along the railway line and the supply of a large amount of housing, and the development of the Tsukuba Express (TX) was the first project to be applied. As a method of development, the housing supply area including the planned construction site of the station will be designated as a priority area, and public facilities such as roads and parks, residential areas, commercial areas, etc. will be designated in the city planning. Then, the land acquired in advance by the railway company or public authorities will be replaced with the land in the priority area. It will be possible to supply a large amount of residential land and housing, and at the same time, it will be possible to contribute to an increase in the number of railway passengers.



Source: Ibaraki pref.

**Figure 18-6: Kenkyu-gakuen Sta. of TX, before (2002) and after (2014)**

In recent years, the method of land value capture (LVC) has been considered as one of the financial resources for rail projects in Japan, and is going to applied to public and private projects (Table 18-6).

LVC is applied to the railway construction, but there is no case of it being applied to the O&M expenditure of railways.

**Table 18-6: Examples of Land Value Capture (LVC) in Japan**

| No. | Method | Scheme | Example |
|---|---|---|---|
| 1 | Air rights | Buying and selling development rights that exceed the floor area ratio (FAR) to finance public works projects | • Reconstruction of Tokyo Sta. building |
| 2 | Land readjustment | Landlords donate part of their own land, jointly develop the area, and allocate part of the generated funds and land to public works. | • Tokyu Den-en-toshi Line<br>• Tsukuba Express line development project |
| 3 | Building an urban redevelopment scheme | Landowners and developers form joint ventures to aggregate fragmented land and create roads and public spaces. Municipalities amend redevelopment land use regulations, such as raising the maximum floor area ratio (FAR) or funding to the project | • Redevelopment of Shiodome area<br>• Redevelopment of Tranomon area |

Source: JTTRI, Case study of LVC of the world biggest cities

## 18.4 Recommendation from JST

JICA Survey Team summarizes the current issues and possibilities of PMRCL's TOD as follows.

- It is proposed that 35% of the yearly projected revenue collected from LVC will be allocated to the O&M expenditure of Patna Metro. LVC income accounts for approximately 8% to 12% of total income.Patna city and PMRCL should concrete introduction scheme for it. The technical assistance from Japan will be effective.
- There are many undeveloped land along the metro corridors. Pana City will able to increase the number of Patna Metro passengers by planning public transportation oriented urban development such as suppling of public housing and new town development. It is necessary to support the preparation of concrete plans for the supply of public housing, the development of residential areas and the realization of transportation oriented urban development.
- Patna city has a plan to redevelop the station square in front of the Patna Junction Station of the Indian Railways which connects to the metro station. By developing this square together with the metro project, the opening effect of the Patna Metro can be greatly enhanced, and leading to the promotion of public transportation users. It is necessary to support to create concret plans for the realization of the station square redevelopment plan.
- PMRCL plans to acquire lands for property development business at Rukanpura Sta., Patna Junction Sta. and ISBT depot Sta. These property developments should consider not only for the revenue but also the increase of passengers. Furthermore, since PMRCL is a public authority, it is important to match the development plan with the city development plan. For this reason, it is important to carefully build a consensus with the supervisory authorities and residents along the corridors for the implementation of the project.

Based on the above considerations, JICA Survey Team would like to propose the services applied for technical assistance and consulting scheme of JICA as follows. (Table 18-7).

## Table 18-7: Proposal of services to be implemented in this project (TOD)

| No. | Program and contents |
|---|---|
| 1 | Capacity development for TOD (transit-oriented development for city planning along metro corridors) |
| | (1) Reasons for proposal<br>Land planning work along metro corridors is outside the business of PMRCL. However, as a public utility company, it is important to work with the city of Patna to promote a transit-oriented city. By cooperating with the city planning of Patna City, PMRCL will be able to formulate more accurate future operation plan and non-fare box business. The proposal is targeted at staff of PMRCL and Patna City, and government officials.<br>(2) Contents<br>• Development of staff for TOD (not real estate development business of PMRCL)<br>• Training in Japan (housing land development projects with public authorities, public-private cooperation business for housing supplying and land development, consensus building among stakeholders, Act on Special Measures concerning Comprehensive Advancement of Housing Development, case study of land value capture (LVC) ), site visits, etc.)<br>(3) Effects<br>• Capacity development of staff of PMRCL and TOD-related organizations such as Patna City<br>• PMRCL will be able to proceed with TOD projects together with public authorities, Transit-oriented urban development can be realized in Patna City.<br>(4) Targets<br>• PMRCL, Patna City, Housing authorities |
| 2 | Redevelopment of the station square of Patna Junction Station, which is connecting to Indian Railways |
| | (1) Reasons for proposal<br>Redevelopment of station area for some Patna Metro stations is already included in the project. However, the square in front of Patna Junction station is bigger than other stations. The station square of Patna Junction Station has been planned for redevelopment. However, at the time of the JICA survey team's survey, financing resources and a specific redevelopment plan had not been planned. In conjunction with the Patna Metro Rail Construction Project, the redevelopment of the station square of Patna Junction station is expected to increase the opening effect of Patna Metro.<br>(2) Contents<br>• Support for financing planning, formulating a redevelopment plan (separation of pedestrians, cars and rickshaws ,securing passengers space, securing parking spaces for buses/rickshaws, securing boarding and alighting spaces, arrangement of traffic rules and access roads around the station, installation of EV charging facilities, installation of security cameras and eco-friendly toilets, etc.)<br>• Support for consensus building among stakeholders (Patna City, Indian Railways, residents, etc.)<br>• Support for bidding, construction management, etc.<br>(3) Effects<br>• The redevelopment of the square in front of Patna Junction Station will be realized.<br>• The square in front of Patna Junction Station will be redeveloped as the face of Patna City.<br>• PMRCL can learn how to coordinate and proceed the project and build consensus among stakeholders.<br>(4) Targets<br>• PMRCL, Patna City, Indian Railways |

Source: JST

# 19. Digital Transformation (DX)

## 19.1 Overview of Existing Studies

### 19.1.1 AFC System

According to the survey by the JICA Survey team, PMRCL plans to apply the Public Private Partnership (PPP) scheme to the procurement of the AFC (Automated Fare Collection) system, and introduce the National Common Mobility Card (NCMC) and QR (Quick Response), which have been developed and recommended for introduction by the Government of India. (Figure 19-1). The PPP model is a scheme in which private funds are used to develop infrastructure such as AFC, and its maintenance is outsourced to private companies. PMRCL is considering integrating this ticketing system with the other public transportation systems such as Patna city buses and Indian Railways. In addition, the bank that issues the NCMC will handle the settlement of charges between transport companies. PMRCL has no plan to set up its own clearinghouse.

Under the policy of One Nation One Card, the Government of India is promoting the development and introduction of the National Common Mobility Card (NCMC) as a smart card which that can be used commonly in public transportation throughout the country. The project is in charge of the national Payments Corporation (NPCI), a non-profit organization which that was established by the Reserve Bank of India and the Indian Bankers Association in 2008, under the initiative of the Ministry of Housing and Urban Affairs (MoHUA). NPCI has established the National Automated Clearing House (NACH) as an institution for clearing charges among operators. This NCMC is a technology developed in India under the national policy of Make in India. It is a contact or contactless smart card which can be used not only for public transportation, but also for highway toll payments, retail stores and ATMs due to its e-commerce functionality. NCMCs are issued by banks and can also be integrated with debit and credit card functions.

Currently, the Indian government is promoting debit cards (RuPay) and digital payment systems (BHIM) for the purpose of popularizing cashless payment methods. RuPay has been developed by the government. And a card payment brand is managed by the Payments Corporation of India (NPCI). It has already been issued by many financial institutions such as major banks in India. BHIM is an electronic payment platform developed by NPCI.

F.No. K-14011/18/2011(Pt.III)
Computer No. 9049079
Government of India
Ministry of Housing and Urban Affairs
Urban Transport Division

Nirman Bhawan, New Delhi
Dated: 09.05.2022

To

As per list annexed

Summary

In a letter issued by the Ministry of Housing and Urban Development (MoHUA) to metro companies in 2019, the introduction of NCMC was directed under the policy of "One nation One Card" announce by the Prime Minister in 2019.

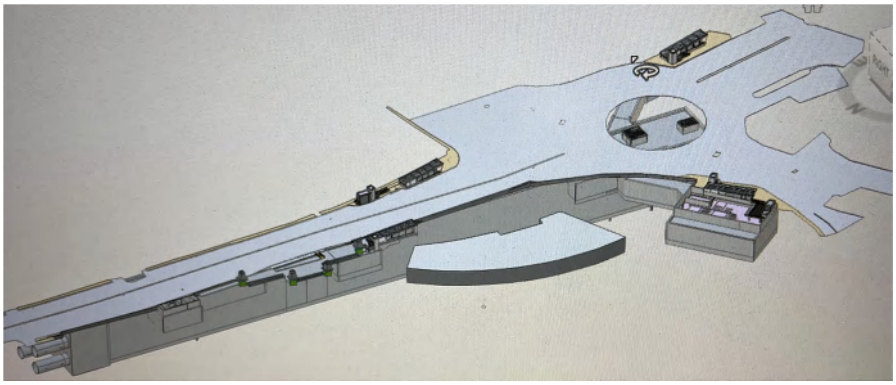
Furthermore, in the letter issued in 2022 (F/No.K-14011/18/2011 (Pt.III) Computer No.9049079), it was ordered to change exclusive contract which did not allow to be used other cards by October 2022, and allow to all card types (debit, credit, pre-paid) under the NCMC technical standard.

Source: PMRCL

**Figure 19-1: Letter issued by the Ministry of Housing and Urban Affairs (MoHUA)**

### 19.1.2 Building Information Modelling (BIM)

PMRCL has developed 3D models for all structures and equipment such as civil structure, station MEP, depot, E&M, signaling & telecommunication facilities, track, and others by using Revit 2021 and 2D drawings can be extracted from the 3D model. BIM will be utilized for further detailed design, construction and project monitoring by contractors. A system for tracking and monitoring project will be introduced, in which 3D models are linked with a detailed work program prepared by the contractor in Primavera P6.



Source: PMRCL/DMRC

**Figure 19-2: BIM Model for PMRCL's Basic Design**

Technical specifications and DMRC guidelines contain detailed requirements for utilizing BIM during the design and construction phase.

PMRCL prepared technical specification of BIM and civil contractors will utilize and update the prepared BIM models. The technical specification shall include the following scopes:

For instance, civil contractors' design works including all station structures as well as tunnel/viaduct and proof checking are assumed to be done using BIM modeling and contractors will be requested to produce, update and present to the engineer on a fortnightly basis an integrated 3D BIM model incorporating track, topography, architecture, structure, plumbing and all other building services. The model will be utilized in design visualization and clash detection of elements as well as the finalization of design works.

During the execution of works, PMRCL will introduce a software package, implementing & maintaining an Integrated Project Monitoring Software (IPMS) which is going to be a cloud-based solution. All the project design drawings in 2D CAD & 3D BIM models will be prepared by contractors and stored in Autodesk's BIM 360 Design. Contractors are supposed to submit their construction & erection programs in Primavera P6 and IPMS shall integrate 3D BIM models stored in BIM 360 Design and Primavera P6 programs with project progress data being picked up from the field using iPad/ Smart phone. Progress monitoring & control shall happen thru outputs depicted 4D BIM and in structured dashboards made available on the cloud at different levels of the DMRC hierarchy for construction management decision support.

The technical specification shall also include training for PMRCL and contractors shall provide appropriate training for PMRCL staff to enable them to make proper use of the software.

## 19.2 Reviews of Existing Studies and Proposals for Improvement

### 19.2.1 Smart card in India

The government of India has developed and is promoting the introduction of the National Common Mobility Card (NCMC) as a smart card that can be used commonly in public transportation throughout the country. The ministry of housing and urban affairs (MoHUA) has an initiative for this project. PMRCL also has a plan to introduce this smart card.

NCMC is a contact or contactless smart card which can be available not only on public transport but also for highway toll payments, retail stores and ATMs with e-commerce functions. NCMCs can be issued by banks and be also integrated with debit and credit card functions. This NCMC is different in type and standard from SUICA, etc., which are introduced in Japanese railways. Felica (Type-C), which is used in SUICA excels in high-speed processing, but is expensive. Currently, in India, it is introduced in the Delhi Metro and others. NCMC, on the other hand, is based on a system called Type-A. This method has the advantage of being cheaper than Type-C,.

As a clearing house, the banks which issued NCMCs will process the procedure for the settlement of fares among operators.

In recent years, metro companies in India have been preparing the introduction under the initiative of the Government of India for promoting this card (Table 19-1).

**Table 19-1: NCMC introduction status in metro companies**

| No. | City | Operator | Available Line | Status of introduction |
|---|---|---|---|---|
| 1 | Ahmedabad | Ahmedabad Metro | All lines | March 2019 |
| 2 | Chennai | Chennai Metro | All lines | February 2022 |
| 3 | Delhi | Delhi Metro | Airport line | December 2020 |
| 4 | Hyderabad | Hyderabad Metro | N/A | Planned |
| 5 | Jaipur | Jaipur Metro | N/A | Planned (Tender was conducted) |
| 6 | Bengaluru | Namma Metro | All lines | October 2021 |
| 7 | Kanpur | Kanpur Metro | N/A | Planned (Tender was conducted) |
| 8 | Kochi | Kochi Metro | N/A | Planned |
| 9 | Kolkata | Kolkata Metro | N/A | Planned (Tender was conducted) |
| 10 | Lucknow | Lucknow Metro | N/A | Planned (Tender was conducted) |
| 11 | Mumbai | Mumbai Metro | N/A | March 2023 |
| 12 | Nagpur | Nagpur Metro | All lines | Introduced |
| 13 | Noida | Noida Metro | Aqua line | Planning |
| 14 | Pune | Pune Metro | N/A | May 2022 |

Source: JST

PMRCL is planning to procure the AFC systems through Public Private Partnership (PPP) scheme. If the PPP scheme is applied for the procurement, the success bidder will be granted for the following rights in exchange for bearing the costs of system installation and O&M for a certain period time widely.

- Exclusive card issuance rights
- Exclusive rights to accept other cards
- Royalty payment from a bank
- Commissions from fare box revenue
- Provision of installation space for ATM/Kiosks, advertisement etc. from the metro company
- Provision of additional services from a bank or operator according to the terms of the contract.

Table 19-2 summarizes the condition when the PPP scheme is applied to the procurement of AFC in metro companies in India. Successful bidders will receive a commission of 4 % of the fare box revenue, as well as rights such as advertising and ATM installation. Royalty income is what is paid at the time of contract, and so-called compensation. It can be said that the smallest the amount, the higher the business feasibility.

**Table 19-2: Terms of tenders for AFC applied PPP scheme for metros in India**

| No. | Operator | royalty income | Exclusive issuance rights | Commission from fare box revenue | Maintenance/ support period | Others |
|---|---|---|---|---|---|---|
| 1 | Kanpur Metro | Rs. 12 Cr | Full contract period | 4% | N/A | • Advertisement rights on ticket vending machines, ticketing gates and QR tickets<br>• Naming rights for 2 stations<br>• ATM installation space at 10 stations. |
| 2 | Kochi Metro | Rs.208.8 Cr | Full contract period | 4% | • Hardware: 6 years,<br>• Softwares:10 years | N/A |
| 3 | Noida Metro | Rs. 42 Cr | 10 years | 4% | • Hardware/Software: 10 years<br>• Employee-leasing for support stations/OCC (AFC): 7 years | • 100 sqm. space for advertisement at each station |
| 4 | Nagpur Metro | Rs. 30 Cr | Full contract period | 4% | • Hardware: Defect warranty 2 years+4 years<br>• Software: Full contract period | N/A |
| 5 | Pune Metro | Rs. 45 Cr | 3 years | 4% | • Hardware: Defect warranty 10 years + spare parts | • 3,000 sqm. space for advertisement at stations |

Source: PMRCL

### 19.2.2 DX, MaaS in India

Many startups provide various services for last-one-mile mobility such as public transportation reservations using mobile apps in India. Many people in Patna city use these services for a reservation and buying a ticket of Indian Railways and booking a rickshaw as well (Table 19-3).

**Table 19-3: Transportation apps widely used in Patna**

| No. | App | Contents |
|---|---|---|
| 1 | OLA | This app is provided by the company whose headquarter in Bangalore, and offers rideshare reservation for cars and bikes. Softbank, a Japanese firm has a stake in this company. This company has business not in India, but also in Australia, New Zealand and UK. In recent years, it has also developed mobile payment services and microfinance business. |
| 2 | UBER | This app comes from USA, and offers rideshare reservation services. This app connect the drivers who are registered with Uber and costumer. In addition to on-demand mobility reservation, it has developed various delivery services in more than 100 countries. In India, Uber started a business in 2013. In Patna, it started a business in 2019.Its services can be available in more than 100 cities in India. Softbank, a Japanese firm has a stake in this company. |
| 3 | Rapido | This app offers a service for booking on-demand mobility. This app connects customers and bike riders registered on this app. The company was established in Bangalore in 2015.<br>In recent years, it has expanded a delivery service with collaboration with e-commerce. Its services can be available in more than 100 cities, including Patna, in India. |
| 4 | IRCTC | This app is developed by Indian Railways. The service has launched in 2022. The long-distance train of Indian Railways can be reserved by this app. The ticket will be delivered on the app. If a printed out ticket is required, the customer can issue a paper ticket at an automatic ticket vending machine or at a ticket window at stations. |
| 5 | UTS | This app is provided by Indian Railways, and launched a service in 2014. Single tickets, commuter passed of suburban trains within 200 km which do not require a seat can be reserved on app. The ticket will be delivered to the mobile as a QR code ticket. If a printed out ticket is required, the customer can issue a paper ticket at an automatic ticket vending machines or at a ticket window at stations. |

Source: JST

In India, many MaaS (Mobility as a Service) -related startups are developing mobilities that can be called “the last one mile” from train stations. Also, due to the EV shift policy of the Government of India, E-buses, E-bikes, E-rickshaws, etc. are becoming popular.

The National Capital Region (NCR) Delhi plans to increase the number of e-buses by 50% by 2023 and accelerate the installation of EV charging stations. In addition to installing EV charging stations every 3km, there are also plans to install them at Delhi Metro stations (Figure 19-3). A similar project is also planned for Bengaluru Metro.




Source: ZEE NEWS

**Figure 19-3: Installation of EV charging station at Delhi Metro station**

The state of Bihar is also promoting the introduction of E-rickshaws, installing EV charging stations along highways, commercial facilities, and residential areas every 50km, and preparing subsidies for the purchase of EV mobility and infrastructure construction.

### 19.2.3 Japanese start-up in India

Terra Motors Co., Ltd., (Terra Motors) established in 2010, manufactures and sells EV mobility in India and Southeast Asia. In India, it has a business to sell EV rickshaws to low-income earners using micro financing scheme, helping to improve their lives. Terra Motors is considering not only the manufacture and sale of EV mobility, but also the development of infrastructure for EV charging facilities to spread EV mobility, and the development of new businesses that combine DX with EV mobility. They also operate in Patna and sell e-rickshaws. (Figure 19-4).



EV-Rickshaw in Patna City




Japanese Startup in Patna

Source: JST

**Figure 19-4: Installing EV charging facilities at Delhi Metro stations E-Rickshaw and Japanese startup in Patna**

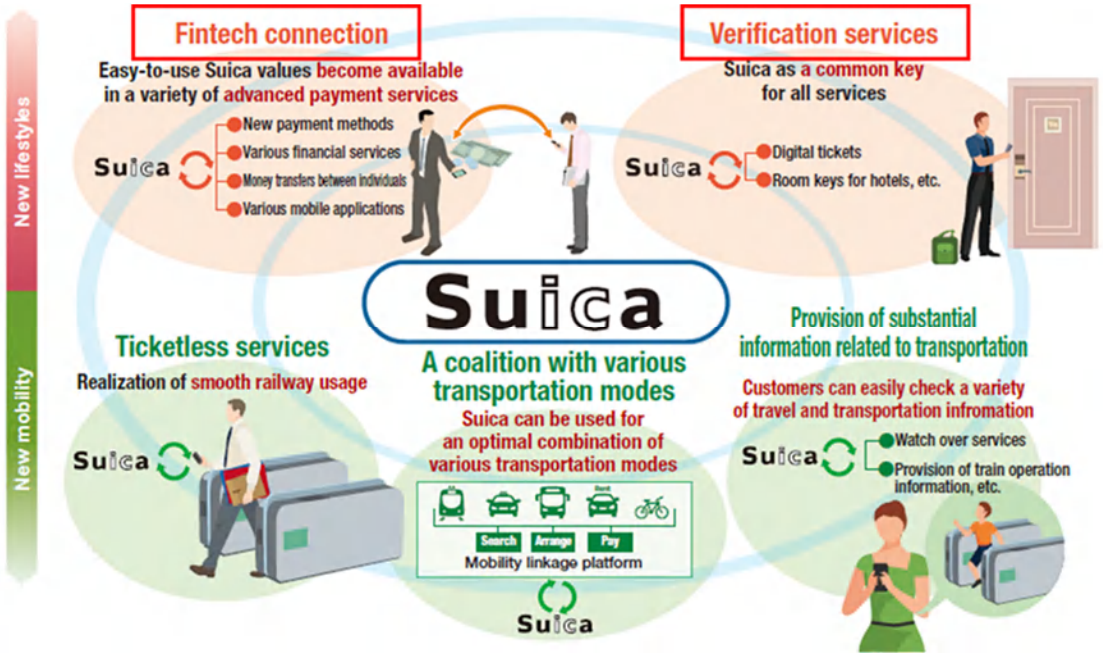
### 19.2.4 Cases in Japan

India has many DX (Digital Transformation) and MaaS (Mobility as a Service) startups. And even in Patna, services such as public transport ticket purchases and ride-sharing services using smartphones are widespread. In the future, Patna Metro will become the axis of public transportation, and in order to promote the use of public transportation, it is necessary for PMRCL to contribute to the promotion of DX and MaaS in public transportation, and to work on improving the business environment together with this metro project. In addition, PMRCL will also need to work to improve passenger services and promote efficient O&M by utilizing DX.

Japanese railway companies are providing new services and improving O&M that utilize DX and MaaS. These examples of DX and MaaS utilization will be of great reference for PMRCL.

#### (1) Expansion of services using smart cards

East Japan Railway Company (JR East) is deploying new services that utilize the functions of the smart card, SUICA (Super Urban Intelligent Card). SUICA has developed new services such as installing SUICA functions on smartphones, digital tickets and room keys for hotels using the authentication function, etc. (Figure 19-5).



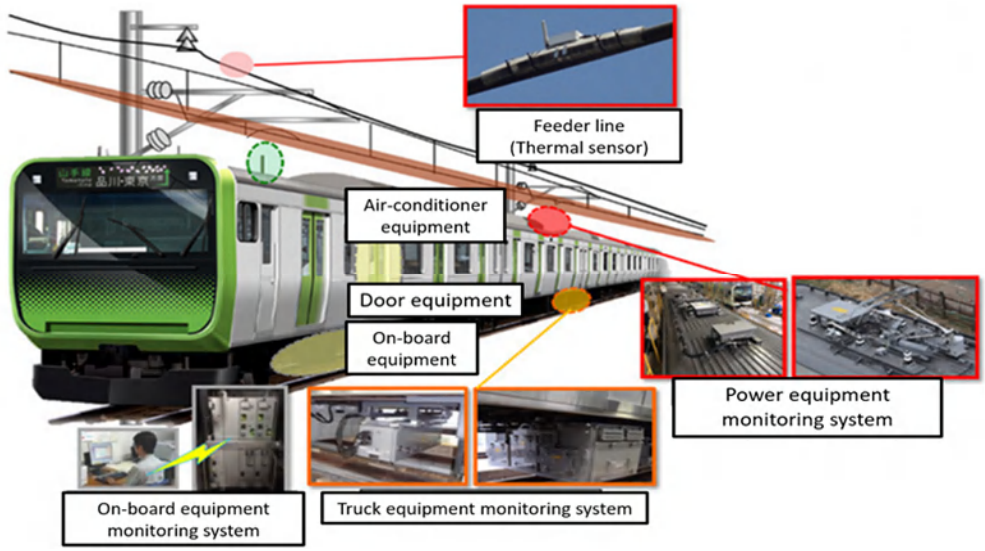

Source: JR East web.

**Figure 19-5: Functions of SUICA**

#### (2) DX for maintenance

The idea of maintenance so far has been based on time-based maintenance (TBM), in which maintenance is conducted periodically regardless of the conditions. However, with the development of DX technology, by constantly monitoring the equipment conditions of the rolling stock and facilities while driving, the big data obtained from the rolling stock can be used and analyzed to automatically check functions, ascertain the deterioration and service life of equipment, and identify failures. The idea of using big data is called

condition-based maintenance (CBM). The maintenance based on CBM is being developed an introduced for improving safety, conducting efficient equipment maintenance, and a reduction in maintenance costs (Figure 19-6).



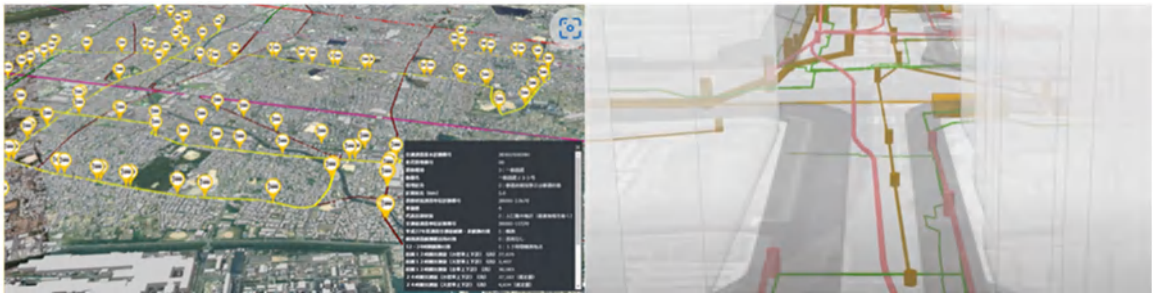

Source: JR East HP

**Figure 19-6: Ground and vehicle facilities monitoring by commercial trains**

### (3) Digital Twin

Advances in IoT sensor and 5G technologies have made it possible to collect various data in real time. A technology called Digital Twin that reflects real-time information has been developed. Digital Twin is being developed for constructing infrastructure models in cyberspace like a twin and reflects real-time data.

By constructing a digital twin, it will be possible to perform various simulations in cyberspace and use it for efficient infrastructure maintenance management and urban planning. Railway companies are also making efforts to unify information and improve works by building a 3D infrastructure model in cyberspace and creating a database together with maintenance information (Figure 19-7).



Source: Ministry of Land, Infrastructure and Transport (MLIT), Transportation Data Platform

**Figure 19-7: Example of Digital Twin**

### (4) On-demand bus

Osaka Metro provides on-demand bus service to provide access to stations for the elderly and other people with limited mobility (Figure 19-8). An on-demand bus does not have a timetable or a fixed route, Users

can reserve boarding, alighting locations, and the date and time by smartphone or phone call. Based on that reservation, AI (Artificial Intelligence) automatically creates the optimal route, enabling services to be provided on an efficient route. Users also have the advantage of being able to easily make a reservation, as well as being able to always sit down.

The introduction of on-demand bus is spreading as a means of last-one mile mobility in suburban areas where route bus services are not feasible for the business.




Source: Osaka Metro

**Figure 19-8: On-demand bus**

### (5) Real-time congestion rate information on a smartphone

In order to provide more comfortable station and train services, JR East provides real-time information on train service cancellations and delays, as well as the congestion status in trains and the congestion status of some stations by mobile app. Passengers can avoid crowded cars when boarding, leading to alleviation of congestion and shortening of boarding and alighting times (Figure 19-9).




Source: JR East

**Figure 19-9: Real time congestion information (JR East App)**

### (6) Digital Signage

The introduction of digital signage using electronic screens is widespread in Japan. By introducing digital signage, it is possible to display multiple advertisements instead of simply renting the place as an advertising space, which is expected to increase sales.



Source: JR East

**Figure 19-10: Digital Signage**

### 19.2.5 Utilizing BIM for O&M

In metro projects, maintenance must be conducted periodically, generally in set periods for preventive maintenance work (see Table 19-4). This is of particular importance in the case of civil engineering structures that support tracks. Preventive maintenance work has a direct impact on the safety of railway operations. Railway management organizations are made of many management groups in various fields. Accordingly, using simulation in maintenance work for detailed planning and as a tool for disseminating information and maintaining ledger records can play a major role in carrying out reliable, consistent maintenance. Labor-saving and efficiency gains can be expected.

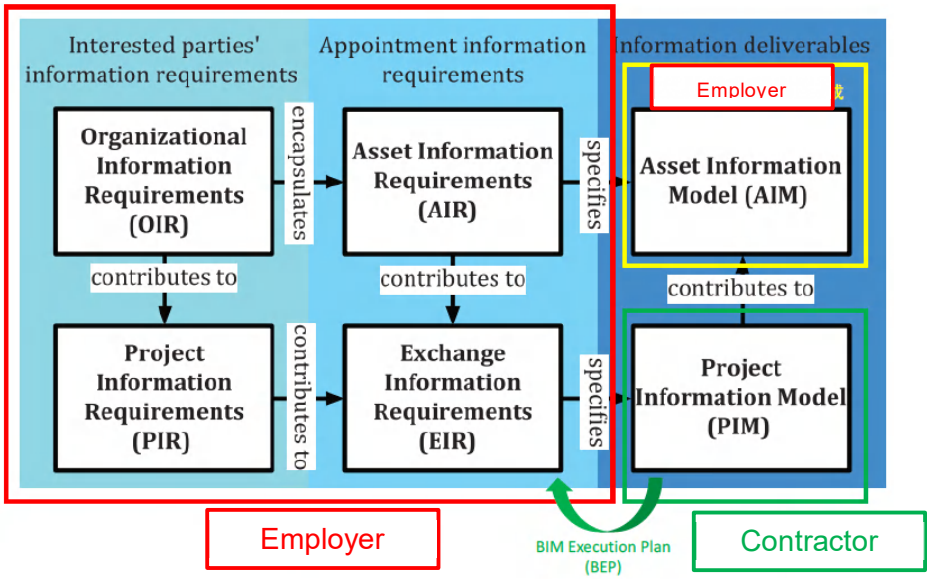
**Table 19-4: Railway maintenance work**

| Structure/Equipment | Purpose | O&M works |
|---|---|---|
| Civil engineering | Track maintenance | Track measurement, rerailing |
| | Structure maintenance (tunnels, bridges, stations buildings) | Visual inspection, detailed inspection, repairs |
| Electrical | Electrical device maintenance (signals, communication, circuits, substations) | Inspect functions, change parts |
| Rolling Stock | Vehicle maintenance | Verify functions, change parts, overhaul |

Source: Data Collection Survey on BIM for ODA Projects (JICA)

PMRCL has already developed comprehensive BIM models and Contractors shall update them as per their progress in detailed design and execution. Besides Contractors shall provide appropriate training for PMRCL staff and utilization during O&M stage is expected. However, a strategy seems to be necessary to utilize BIM models for O&M stage until Contractor's BIM data handover to PMRCL.

For instance, ISO 19650 describes various information-related requirements (Information Requirements) and information models (Information Models) needed between the client and contractor to build information in BIM (see Figure 19-11). The client information requirements (EIR) are requirements that are presented to the bidder prior to contractor selection and contracting, and are ordering requirements that specify the level of detail of the BIM data to be delivered for the project, the project process, operational methods, and the division of contractual roles, etc. The BIM Execution Plan (BEP) is a document that is submitted by the bidder to the client to propose how BIM will be used in the project.




Source: ISO19650-1

**Figure 19-11: Relationship between Various Information Requirements and Information Models**

Developing Asset Information Model (AIM), which includes information necessary to support asset management providing all the data and information required for the operation of assets, is expected to develop in early stage.

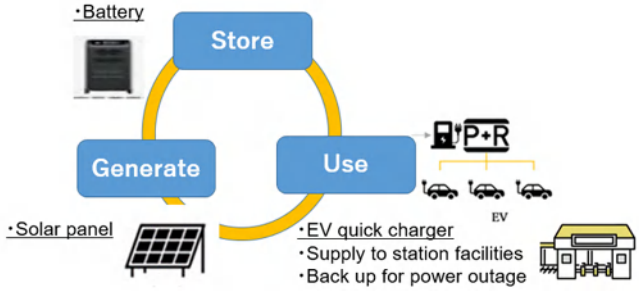
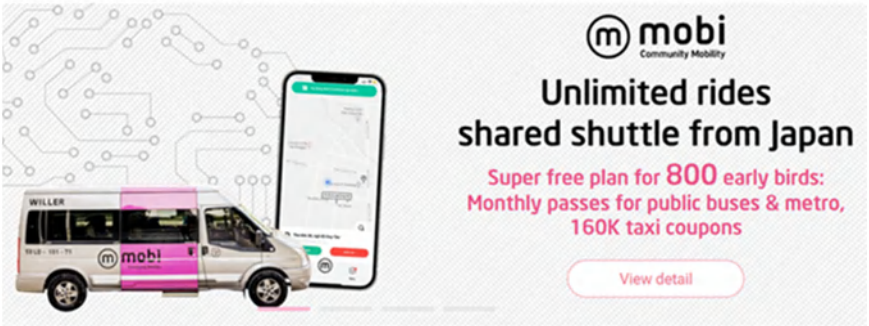
## 19.3 Recommendation from JST

JICA Survey Team summarizes the current issues and possibilities of DX for PMRCL as follows.

- It is important to introduce DX technologies to realize efficient O&M and non-fare box business.
- PMRCL has a plan to introduce NCMC (National Common Mobility Card) and QR code type tickets which are developed and recommended by the Government of India, and is considering applying the PPP scheme for the procurement of AFC system. Therefore, it might be difficult for PMRCL to develop its own services using smart cards.
- In India, the government is leading the shift to EVs for mobility. In addition, along with the metro projects, many MaaS-related startups that provide last-mile mobility are developing services.
- Patna Metro will become the axis of public transportation, and in order to promote the use of public transportation. And it is necessary to contribute to the promotion of DX and MaaS in public transportation. In order for the services introduced by Patna Metro should be mutually usable with other public transportations. It is necessary to unify the system through cooperation between the relevant government agencies and other public transportation operators, and to develop an introduction plan. Public relations activities such as IC card acquisition campaigns are also important to promote the use of public transportation.

Based on the above considerations, JICA Survey Team would like to propose the business trials using JICA scheme as follows. (Table 19-5).

## Table 19-5: Proposal of services to be implemented in this project (DX)

| No. | Program and contents |
|---|---|
| 1 | Installation of EV charging facilities at metro stations and business trial for commercialization of selling solar power electricity |
| | (1) Reasons for proposal<br>Currently, the Government of India is promoting the shift to EV motilities, and Delhi Metro and Bengaluru Metro are planning to install EV charging facilities at stations. Efforts to shift to EV are also underway in the state of Bihar. PMRCL plans to install solar panels on the roof of the station. However, for efficient use of solar generated electricity, it is important to install a storage battery as well. By installing storage batteries and EV charging equipment in addition to solar panels, along with subway construction, it will be possible to supply to EV motilities. And it is a possibility for PMRCL to establish selling electricity business as a non-fare box business.<br>(2) Contents<br>• Installation of solar panels, large-capacity storage batteries, and high-speed EV charging facilities at metro stations<br>• Business trial of selling electricity to EV motilities<br>(3) Effects<br>• The policy of EV shift of the Government of India will be supported and promoted.<br>• The number of EV charging stations in Patna City can be increased.<br>• Selling solar power electricity to EV motilities may become one of non-fare box business of PMRCL.<br><br><br>Source: JST<br>Picture: Business model of EV charging stations<br>(4) Target<br>Patna City, PMRCL, private EV operators |
| 2 | Business trial for on-demand mobility business |
| | (1) Reasons for proposal<br>In India, startups of last mile mobility related to MaaS etc. are popular. In Patna City, as well, train and taxi reservations using smartphone apps are widely practiced. On-demand mobility bus services that can be summoned and boarded regardless of route or time have been developed and introduced as last-mile mobility from railway stations and bus stops in some countries. In the future, as residential development is carried out along the Patna metro lines, it will become an issue to consider means of access to the station in the suburban area. On-demand buses have the potential to be commercialized as one of the last-mile mobility options for PMRCL.<br>(2) Contents<br>• Development of smartphone application for on-demand bus<br>• Promotion of public transportation and on-demand buses<br>• Demonstration experiment of on-demand bus<br>(3) Effects<br>• PMRCL can provide last-mile mobility in suburban areas.<br>• On-demand bus may become one of PMRCL's non-fare box business.<br><br><br>Source: Willer Express<br>Picture: Business trial for on-demand bus by a Japanese firm in Hanoi, Vietnam<br>(4) Target<br>Patna City, PMRCL, Private ICT companies, Taxi/Bus Operators |

Source: JST

# 20. Non-Fare Box Revenue

## 20.1 Overview of Existing Studies

The fields of non-fare business that PMRCL is planning include advertising, parking, filming of movies, installation of communication cables, sale of station naming rights, and rental of station space such as kiosks. These revenue estimates are calculated by converting the differences in economic growth rate and income in Bihar state, using examples of other metros in India such as Chennai Metro and Jaipur Metro as benchmarks (Table 20-1). These businesses are common among other metro companies in India.

The revenue estimates for each field of every five years from FY2024 to FY2051 are as follows (Table 20-2).

**Table 20-1: Rate for Non-Fare Box Revenues**

| Type of revenue | Unit rate | Rate of increasing | Remarks |
|---|---|---|---|
| Advertising panels inside station and train coach | 2,000 per sqm per month in 2018 | 5%/year | Estimated 50 % of the case of Chennai Metro, considering the differences in earnings. |
| Advertisement on external train wrap | Rs. 1.25 lakh/car/month | 5%/year | Estimated 50 % of the case of Chennai Metro, considering the differences in earnings. |
| Parking charges at stations | Average 4 hour<br>Rate for 3-6 hours: Rs.20<br>Rate for 6-12: Rs 30<br>Plus 20 % for time slots and vehicle variations | 15 %<br>every 3 years | Reference of the business condition in Patna |
| Film shooting charges | Rs. 2 Lakh per hour for inside<br>Train/station assumed for 8 hours and once in 8 months, 12 hours in a year | 5%/year | Estimated of case of Chennai Metro, considering for introducing initial promotion |
| Telecom cable license fee | 2,000 per month for entire track lengths, 50,000 per month for elevated stations | 10 %<br>every 2 year | Estimated of case of Chennai Metro, considering for introducing initial promotion |
| Telecom Tower license fee | 15,000 per month for elevated stations | 10 %<br>every 2 year | Estimated of case of Chennai Metro, considering for introducing initial promotion |
| Semi naming rights of station building | 75 Lakh per year per station | 25 %<br>every 5 year | Reference of other metros |
| Kiosk rentals | 700 per sqm per month | 5%/year | Reference of Jaipur Metro |

Source: DPR Table 19-12, Modified by JST

**Table 20-2: Non-Fare Box Revenue**

| Revenue Stream | Total revenue (Rs. In Crore) | | | |
|---|---|---|---|---|
| | 2024-25 | 2031-32 | 2041-42 | 2051-52 |
| Advertisement | 94 | 148 | 250 | 406 |
| Rentals from Kiosks | 4 | 6 | 10 | 16 |
| Parking | 3 | 4 | 7 | 11 |
| Film Shooting | 0 | 1 | 1 | 1 |
| Telecom Cable and Tower (licence fees) | 2 | 2 | 3 | 6 |
| Semi naming rights of stations | 13 | 18 | 30 | 49 |
| Total | 116 | 179 | 301 | 489 |

Source: DPR Table 19-14

The fields of non-fare box businesses mentioned above are basically the space rental business. It is an effective utilization of floors and walls of stations, and dead space of owned properties. Therefore, there is limited space available for rent, and revenues from continued business expansion cannot be expected. The increase in revenue is due to the inflation rate.

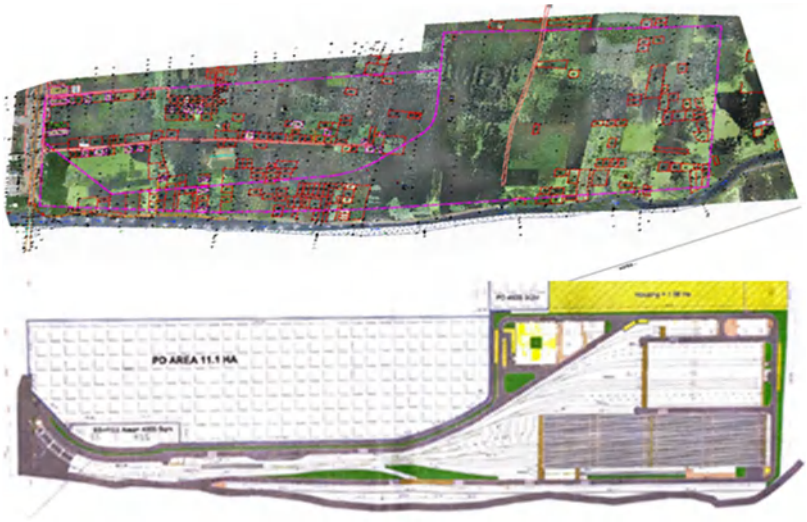
Non-fare box revenue of PMRCL consists of the above businesses, land value capture (LVC) of TOD, and income from property development business. However, regarding TOD, no specific LVC scheme has been decided in Patna, and it is calculated with reference to the National Transit Oriented Development (TOD) policy issued by the Government of India. It is proposed that 35% of the yearly projected revenue collection from LVC will allocate to Patna Metro.

The forecast for non-fare box revenue of PMRCL will be temporarily negative due to real estate development investment, but it will turn positive after 8 years (Table 20-3). PMRCL has plans to acquire privately owned land adjacent to ISBT depot (Figure 20-1). This plan is to establish a special purpose vehicle (SPV) with a private developer, acquire 11.3 Ha of privately owned land adjacent to ISBT depot, and construct a commercial building for rent and residential apartments for sale. At the time of study of JICA Team, PMRCL was discussing the financing and business plan with a private developer. But the plan had not been confirmed yet. There is another option that PMRCL owns and develops by itself. This land is close to the bus terminal and also the terminal station of the metro. In addition, considering a large amount of land, attracting shopping malls, which can be expected to increase the number of metro passengers, will be also a good utilization plan.

**Table 20-3: Estimation of Non-Fare Box Revenue for Patna Metro (Rs. In Crores)**

| Year | TOD | Property Development | Non-Fare Box Business (Other sources) | Total |
|---|---|---|---|---|
| 2024-25 | 193 | 281 | 116 | 590 |
| 2027-28 | 223 | -119 | 135 | 239 |
| 2030-31 | 258 | -92 | 156 | 322 |
| 2033-34 | 299 | -64 | 198 | 433 |
| 2036-37 | 346 | 18 | 227 | 591 |
| 2039-40 | 401 | 21 | 262 | 684 |
| 2042-43 | 464 | 25 | 315 | 804 |
| 2045-46 | 537 | 28 | 365 | 930 |
| 2048-49 | 622 | 33 | 422 | 1077 |
| 2051-52 | 720 | 38 | 489 | 1247 |

Source: DPR Table19-25 modified by JST




Source: PMRCL

**Figure 20-1: Planned acquisition land adjacent to ISBT Depot**

The ratio of non-fare box revenue of PMRCL's total revenue is 35% in 2024, but it is estimated to decrease to 19% in 2051 due to the increase in fare box revenue according to the contribution of property development and the increase in passenger numbers (Table 20-4).

**Table 20-4: Ratio of Non-Fare Box Revenue (Rs. In Crore)**

| Source of Revenge | 2024 | 2031 | 2041 | 2051 |
|---|---|---|---|---|
| Fare Box Revenue | 934 | 1,886 | 3,003 | 5,293 |
| Non-Fare Box Revenue | 590 | 368 | 765 | 1,247 |
| Total Revenue | 1,524 | 2,254 | 3768 | 6,540 |
| Percentage of Non-Fare Box Revenue (%) | 35 | 16 | 20 | 19 |

Source: DPR Table 19.16 modified by JST

## 20.2 Reviews of Existing Studies and Proposals for Improvement

The ratio of non-fare box revenue in PMRCL's total revenue is close to that of Chennai Metro, which is used as a benchmark data for revenue estimation. However, it can be said that it is low compared to Delhi Metro and overseas operators in Hong Kong and Singapore (Table 20-5). It can be said that these cities are not only relying on fare revenue, but are actively working to increase non-fare revenue.

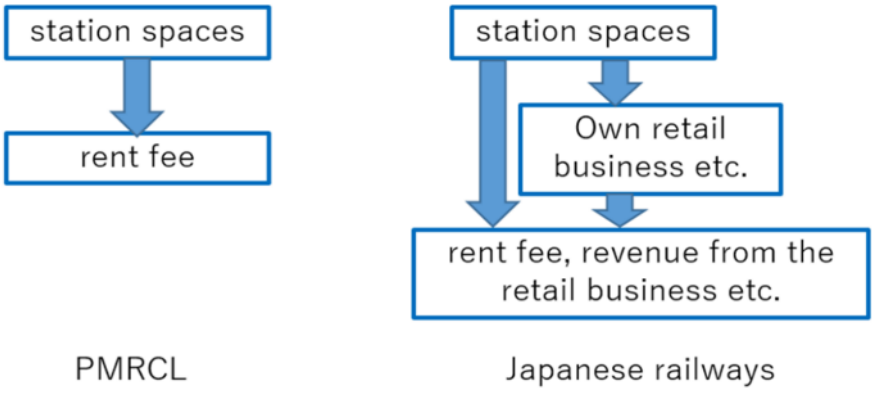
**Table 20-5: Revenue Breakdown for Metro Operators （FY2020）**

| Metro Company | Revenue (%) | | | Others (%) | Total (%) |
|---|---|---|---|---|---|
| | Total Business Revenue | Fare Box Revenue | Non-Fare Box Revenue | | |
| Delhi | 85 | 48 | 37 | 15 | 100 |
| Mumbai | 103 | 89 | 14 | -3 | 100 |
| Bangalore | 88 | 79 | 9 | 12 | |
| Chennai | 58 | 42 | 16 | 42 | 100 |
| Transport for London | 63 | 52 | 11 | 37 | 100 |
| MTR Hong Kong (FY2019) | 88 | 32 | 56 | 12 | 100 |
| SMRT Singapore (FY 2016) | 99.7 | 71 | 28 | 0.3 | 100 |
| Tokyo Metro (FY 2019) | 100 | 80 | 20 | 0 | 100 |
| Osaka Metro (FY 2019) | 100 | 86 | 14 | 0 | 100 |

Source: Performance of Indian Metro Systems, UITP

PMRCL is planning basically space rental business such as kiosk, advertisement, parking lots and installation space for communication cables which utilize dead spaces of metro facilities, same with the business of other metro companies in India. However, the revenue from these type of space rental busineses is limited. Because they are proportional to the amount of space that can be rented out.

In the business model of Japanese railways, there are cases that the contract of kiosk in stations is not only renting the space. In the contract, a railway company can get a certain share in accordance with sales of kiosk. This type of contract can make win-win relation between the lesser and lessee. The railway company make efforts to maximize sales together with the lessor. The railway company conducts marketing research and arrange the spaces in consideration of the passenger flow etc.




Source:JST

**Figure 20-2: Difference of Business model**

The business strategies and contract models of Japanese railways will help to increase non-fare box business of PMRCL.

There are no regulations or guidelines for the non-fare business of PMRCL at the time of the JICA Team's study. However, since PMRCL is a public authority, it might be difficult to refer to the successful non-fare box business model of Japanese railways, most of which are private companies. Also, in an actual project, it is difficult to keep the number of passengers as planned (Table 20-6). First of all, in order to increase the number of passengers, it will be necessary to change the negative image of public transportation in Patna.

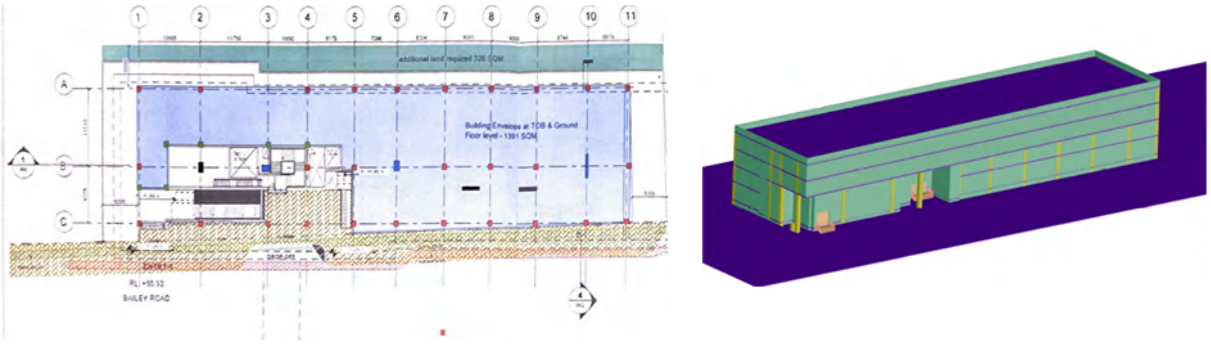
**Table 20-6: Comparing Planned and Actual Passenger Rates for Metro Projects in India**

(Fiscal year)

| Metro Company | Projected daily ridership (million) | | | Average daily ridership (million) | | | Ridership achieved (%) | | |
|---|---|---|---|---|---|---|---|---|---|
| | 2018 | 2019 | 2020 | 2018 | 2019 | 2020 | 2018 | 2019 | 2020 |
| Delhi Metro | 6.8 | 7.0 | 7.2 | 2.5 | 4.0 | 5.7 | 38 | 58 | 79 |
| Mumbai Metro | 0.6 | 0.6 | 0.6 | 0.4 | 0.3 | 0.5 | 68 | 57 | 74 |
| Bangalore | 1.3 | 1.4 | 1.5 | 0.3 | 0.3 | 0.4 | 24 | 24 | 27 |
| Chennai Metro | 0.8 | 0.9 | 0.9 | 0.02 | 0.1 | 0.1 | 3 | 9 | 13 |

Source: UITP, Performance of Indian Metro system: lessons for upcoming urban rail project

PMRCL has plans to acquire land adjacent to Rukanpura Sta., Patna Junction Sta. for property development in addition to developing a property adjacent to ISBT Depot. Property development should be carried out with the aim of increase in metro passengers. At Rukanpura Sta., the land about 1,400 sqm is planned to be acquired and developed for the revenue (Figure 20-3). Considering the size of this property, it is assumed that the competitiveness in Patna City, it can be proposed that a hospital or medical complex, vocational school, vocational school, offices. Especially patients and students are more likely to use public transportation, which will contribute to an increase in metro passengers.



Source: PMRCL, JST

**Figure 20-3: Planned property development site and plan at Rukanpura Sta.**

Table 20-7 shows trends in non-fare businesses of metro and railway operators in India.

**Table 20-7: Trends in non-fare box business of Indian metro/railway companies**

| No. | Metro Company | Contents |
|---|---|---|
| 1 | Delhi Metro | • The policy for renting station space to kiosks and retails is published. The policy stipulates contract procedures, contract terms and permitted business fields.<br>• The company sells the station naming rights through an online auction conducted by the external outsourced advertisement company. The contract period is for 10 years and the winning bidder will be able to name the station to promote their brand. In addition to naming the station, Sikanderpur Sta. also repainted the exterior of the station in orange, the brand colour of the winning bidder.<br>• Aiming to increase the number of passengers, the feeder services, so-called connecting buses, that connect each station to surrounding residential areas are operated. About 270 minibuses are already in operation to connect with metro stations. In 2018, it announced plans to add 242 electric minibuses and 288 compressed natural gas (CNG) buses. At some stations, eco-friendly electric auto rickshaws have also been introduced.<br>• The mobile application has been introduced to provide information such as route finder, and sightseeing information around the station. |

| No. | Metro Company | Contents |
|---|---|---|
| 2 | Bengaluru Metro | • The state of Karnataka and Bengaluru city have a policy to create a world-class business environment for startups. Under this policy, Bengaluru Metro sees the stations where people gather as an advantage and has set up incubation centers for startups at the stations.<br>• Bengaluru Metro has not plan of the introduction of vehicle wrapping advertisements considering the harmony with the urban landscape. On the other hand, digital signage using LED screens at stations are introduced widely. |
| 3 | Chennai Metro | • In addition to the existing depot, Chennai Metro is constructing a new depot on a 4,800 sqm site adjacent to Wimco Naga Sta. In the future, there is a plan to build a 20-story building that integrates residential and commercial facilities above the depot for non-fare box revenue.<br><br>Source: The Times of India |
| 4 | Noida Metro | • Noida Metro decided to rent unused parking lots to food trucks. Nine out of 15 stations are be available. The minimum rental space at each station is 25 sqm. Leasing of the space will be carried out by tender. The opening hour of food truck is from 9:00 am to 10:30 pm. Noida Metro expects it to be a new effective way to utilize unused properties. |
| 5 | Nagpur Metro | • Nagpur Metro plans to build a station building with 18 floors above ground and 2 floors below ground at Zero Mile Freedom Park Sta. The station building is planned to have commercial facilities and parking lot. The project will be implemented through a public-private partnership (PPP), with the successful bidders receiving the right to operate the parking lot and commercial facilities for 60 years (including three years for construction). The successful bidder can decide on the design and facilities of the station building, such as hotels, restaurants, commercial facilities, and offices.<br><br>Source: Nagpur Today |
| 6 | Mumbai Metro | • Mumbai Metro has signed a contract with a consulting firm to increase non-fare revenue. In addition to current business of advertisement, retail and real estate development along corridors, Mumbai Metro will consider effective utilization of assets such as air rights of unused facilities. |
| 7 | Indian Railways | • Indian Railways is openly soliciting innovative ideas to increase non-fare box revenue by utilizing assets without compromising passenger convenience and comfort. Applicants are required to make proposals including technical feasibility, market size, profit forecasts, etc. |

Source: JST

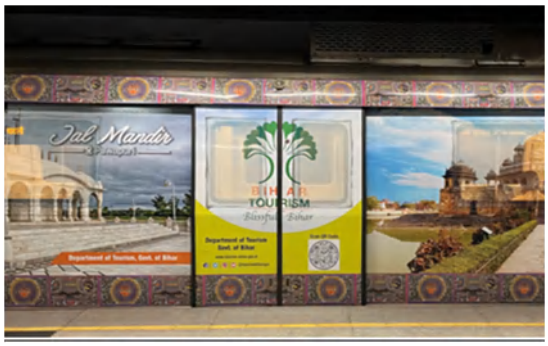
Figure 20-4 shows examples of kiosks and advertisement at Delhi Metro and Indian Railways stations surveyed by the JICA Team.




Kiosk (Indian Railway)




Advertisement (Indian Railway)




Vehicle rapping advertisement (Delhi Metro)




Kiosk (Delhi Metro)

Source: JST

**Figure 20-4: Examples of various non-fare box business of metro and railway companies in India**

## 20.3 Cases in Japan

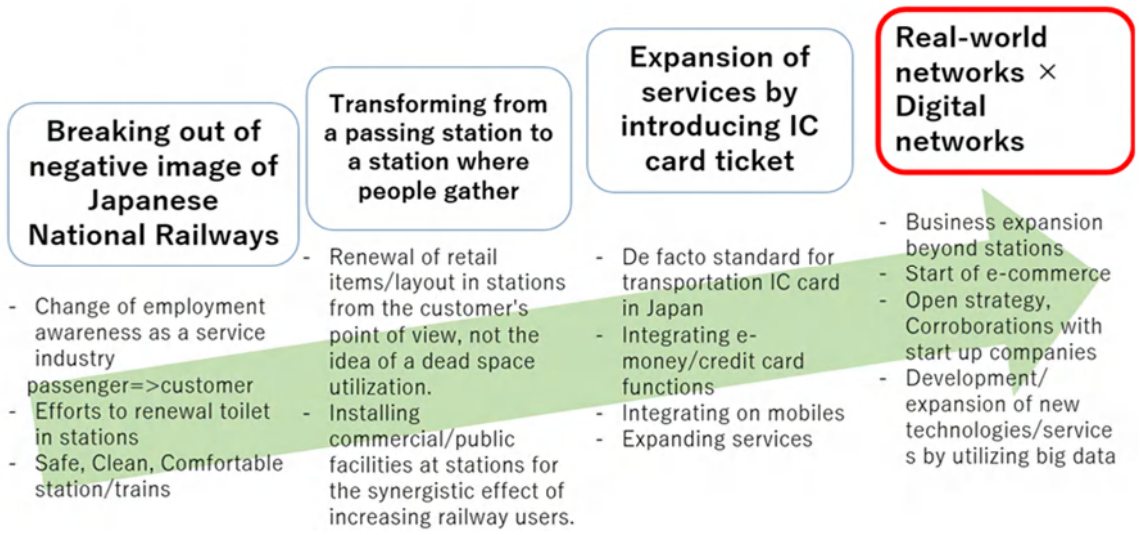
Over the past few years, metro and rail companies in India and around the world have faced a difficult business environment with a reduced number of passengers due to COVID-19. In addition, even if COVID-19 is over, it is expected that the previous lifestyle will not come back again. The companies are re-assessing its business strategies to adopt to the "new normal".

Figure 20-5 shows the transition of non-fare box business strategies of East Japan Railway Company (JR East), which has succeeded in the so-called in-station business and created various non-fare box business. JR East is one of the passenger railway companies which were born in 1987 by the privatization of Japanese National Railways. As a private company, JR East is required to operate independently without relying on subsidies from the government.

At first, JR East had focused on changing the bad image of the state railway (dangerous, dirty, poor service) before developing non-fare box business. The service before privatizing was at the level of just allowing passengers to use the railways. Therefore, JR East, as service provider, made efforts to reform the mindset of its employees. JR East instructed employees to call passengers customers. In addition, JR East had carried

out a campaign to clean-up toilets in the stations in order to symbolize the change and reborn of the railway.

After that, JR East focused on the expansion of retails in station areas by reviewing the layout of the commercial facilities from the customer's point of view as a station where customer gather rather than pass through. And then, along with the use of e-money integrated with a smart card, and expanded its services such as lockers and hotel entrance keys using authentication functions of the card. In addition, by reviewing underutilized assets such as spaces under the viaduct, JR East has developed and expanded the possibility of non-fare box business. JR East was cooperating with local municipalities to effectively utilize the space under the viaduct, which was created by the elevation project of the Chuo line, five stations between Mitaka and Tachikawa, about 9 km. JR East is developing non-rail business as well as enhancing the appeal of areas along the railway line through integrated development of the city planning. This experience can be useful for PMRCL to enhance the security level and scenery along the corridors, as well as the possibility of non-fare box business (Figure 20-6). Kintetsu Railway Co., Ltd (Kintetsu) started the rental business of house and garage integrated residence utilizing the space of under the about 42 km length of the viaduct as well (Figure 20-7). For example, after anonymizing personal information, "Station Chart" is created from the usage data of SUICA. It includes the analysis of the monthly usage status at each station, and can sell to external companies in addition to in-house marketing. It is used for urban planning by local governments and for the creation of marketing strategies by surrounding companies.




Source: JST

**Figure 20-5: Transitions in JR East's Non-Railway Business Strategies**

As a post-pandemic strategy, JR East is pursuing new business possibilities by fusing stations as a real place where people gather with IoT data which is collected by smart cards or e-commerce business. Through an open innovation strategy, JR East is developing new services such as the use of big data through collaboration with startups and other industries. Big data has the potential to be used for city planning and corporate marketing, and to create new services.

| | |
|---|---|
|  |  |
| Retails utilizing the space under viaduct | Rest space under the viaduct |
|  |  |
| Walkway along viaduct | Student house using the space under viaduct (length of 350 m) |

Source: JST

**Figure 20-6: Utilization of the space under viaduct (JR East)**




Source: Kintetsu Group HP

**Figure 20-7: Rental business of house and garage integrated residence using the space of viaduct (Kintetsu)**

## 20.4 Recommendation from JST

JICA Survey Team summarizes the current issues and possibilities of PMRCL's non-fare box business and revenue as follows.

- For the success of non-railway business, it is important to provide clean, safe and comfortable public transportation service.
- The business that PMRCL is planned is basically a place rental business, so the growth of the revenue is limited. It is important to benchmark other metro operators in India and get about 20% of operating revenue from non-fare business as planned.

- In addition to measures for increasing the number of passengers, it is important to increase the ratio of non-fare box revenue for independent management. Using the Chennai Metro, which is a precedent case in India, as a benchmark, it is important to obtain about 20% of business revenue from non-fare box revenue as planned. Therefore, it is important to develop human resources for non-fare businesses and to develop business plans before opening.
- PMRCL is considering acquiring private land around the depot, and is proceeding with a development plan in collaboration with a private developer. There is also a plan to acquire and develop lands adjacent to Rukanpura Sta. and Patna Junction Sta. It is important to prepare for non-fare box business and property development business from an early stage.

Based on the above considerations, JICA Survey Team would like to propose the services applied for technical assistance and consulting scheme of JICA as follows. (Table 20-8).

**Table 20-8: Proposal of services to be implemented in this project (Non-Fare Box Business)**

| No. | Program and contents |
|---|---|
| 1 | Capacity development for non-fare box business (retails/advertisement in station area etc.) |
| | (1) Reasons for proposal<br>For other metro projects, consideration of non-fare box business will start after the operation stabilizes after opening. However, the non-fare box business is important not only to supplement the revenue of the metro business, but also to realize self-sustaining financing. JICA Survey Team proposes to start considering non-fare projects in parallel with preparations for subway projects.<br>(2) Contents<br>• Capacity development of staff for non-fare box businesses (station retails, advertising, etc.)<br>• Training in Japan (Non-fare box business strategies after Covid-19, marketing, organizational structure, cooperation between lessors/lessees, site visit of non-fare box business, etc.)<br>• Support for planning of strategies, business plans, marketing, etc.<br>• Support for business operations, revenue management of non-fare box business, etc.<br>(3) Effects<br>• Capacity development of staff of non-fare box business<br>• PMRCL can learn the know-how of non-fare box business of Japanese companies<br>• PMRCL can learn business strategies and trends of non-railway businesses after Covid-19.<br>• PMRCL will be able to plan and operate efficient non-fare box business. |
| 2 | Capacity development for non-fare box business (property development business) |
| | (1) Reasons for proposal<br>Property development business is one of the major non-fare box revenue for railway companies. PMRCL has a plan to acquire private land around the planned depot site for real estate development business. For the success of the real estate business, it is important for PMRCL to take the initiative in raising funds, developing plans, building consensus among stakeholders, etc.<br>(2) Contents<br>• Capacity development of staff in non-fare box business (property development business)<br>• Training in Japan (business model and strategy of real estate development business, organizational structure, business operation and profit management, case study of land value capture (LVC) in Japan, site visit, etc.)<br>• Support for business plans, funding plans, and consensus building among stakeholders<br>• Support for business management and revenue management<br>(3) Effects<br>• Capacity development of staff in the property development business.<br>• PMRCL can learn the know-how of Japanese railways companies.<br>• PMRCL will be able to plan and promote real estate business on its own.<br>• PMRCL will be able to operate and manage the property development business by itself. |

| No. | Program and contents |
|---|---|
| 3 | Trail for measures to improve the level of safety, security, and cleanliness in and around stations |
| | (1) Reasons for proposal<br>Many residents of Patna City have an image that public transportation is dirty and dangerous. They would like to avoid using it if possible. Improving the image of public transport is essential for the business operation and development of metro projects. In Japan, railway companies are working together with local governments and local residents to improve security and beautify areas around stations, as well as to introduce effective security equipment. The knowledge of these Japanese companies will be useful for PMRCL.<br>(2) Contents<br>• Support for improving security and cleanness level around stations in collaboration with local authorities and local residents<br>• Support for measures to promote the use of public transportation<br>• Installation of lighting around stations, security equipment (security cameras, mosquito sound generators which can avoid especially young people gathering and improve security level around stations, etc.)<br>• Business trials such as installation of environmentally friendly toilets through public-private partnership schemes etc.<br>(3) Effects<br>• PMRCL can realize safe and clean public transportation by learning the knowledge of Japanese railway experiences and technologies.<br>• As a result, the increase of fare box and non-fare box revenue can be expected as the number of passenger's increases. |

Source: JST

# 21. Financial Analysis

## 21.1 Overview of Existing Studies (N/A)

## 21.2 Applied Preconditions and Methodology for this Study (N/A)

## 21.3 Financial Structure of Borrowers

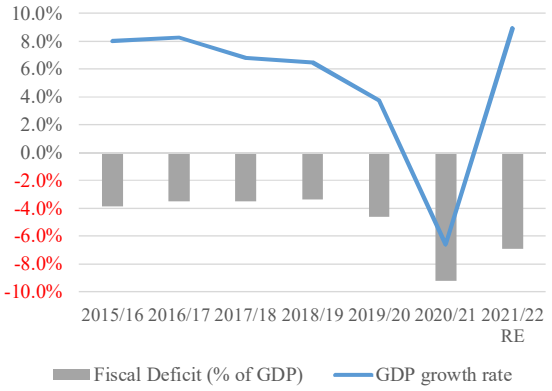
### 21.3.1 Financial Capacity Analysis of the Central and State Governments

#### (1) Central Government

1) Fiscal balance and budget expenditure

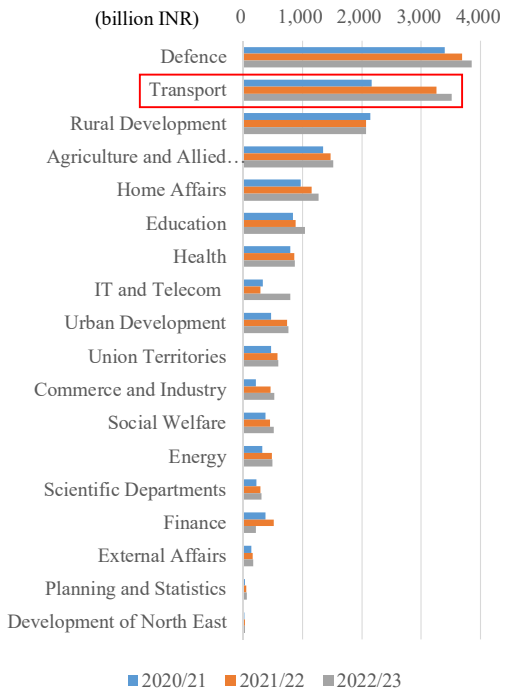
During the year 2020-21, the shortfall in revenue collection due to the interruption in economic activity and the additional expenditure created immense pressure on the available fiscal resources. As a result, the fiscal deficit for 2020-21 was 9.5% of GDP. The Medium-Term Fiscal Policy (MTFP) Statement presented with Budget 2021-22 envisaged a fiscal deficit target of 6.8% of GDP for 2021-22. The GDP growth rate also deteriorated by -6.6% in 2020-21 but will be expected to recover by 8.95% in 2021-22 (Figure 21-1)**.**

The Union Budget 2021-22 had enhanced the budget for more productive capital expenditure. The Government budgeted for a 34.5 % growth in capital expenditure over 2020-21 – with emphasis on railways, roads, urban transport, power, telecom, textiles and affordable housing amid continued focus on the National Infrastructure Pipeline. The National Infrastructure Pipeline covering 6,835 projects was expanded to 7,400 projects in Budget 2021-22 (Union Budget 2021-2022). The transport sector was the second most budgeted sector after the defense, totaling Rs. 351,851 Crore in 2022-23 (Figure 21-2). The capital investment in the transport sector will continue to be a key drive of the high economic growth of the country.




Source: MoF

**Figure 21-1: Fiscal Deficits and Real GDP Growth Rate**



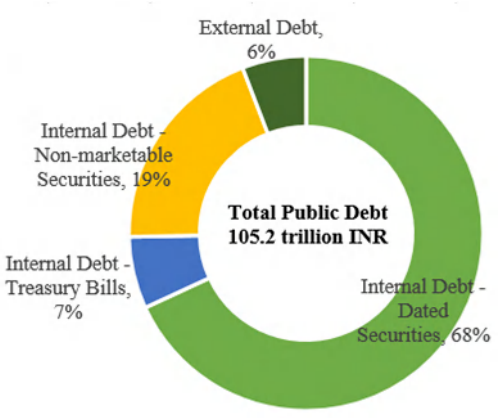

Source: MoF

**Figure 21-2: Major Expenditure Items**

## 2) Public Debit

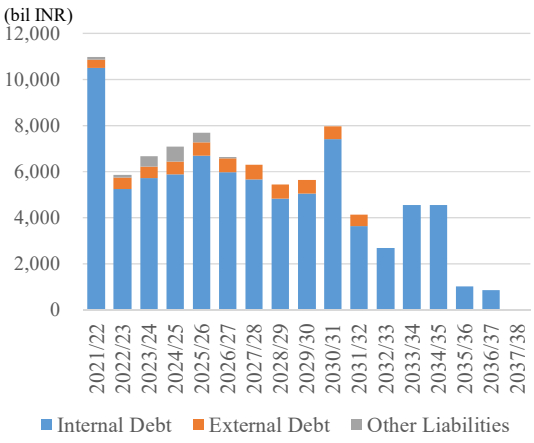
The public debt indicators of India shows that the currency risk associated with debt portfolio continues to be low since it is predominantly of domestic origin and denominated in domestic currency. The low share of external debt, almost entirely from official sources and on concessional terms, provides a safety net from volatility in the international financial markets (Figure 21-3).

External debt (at the current exchange rate) as a percentage of total public debt was 6% in 2020-21. This is indicative of low currency risk of debt portfolio of the Central Government (Figure 21-4). The redemption profile of public debt also shows the majority of internal debt, concentrated in less than 10 years maturity period (Figure 21-4).




Source: MoF

**Figure 21-3: Public Debt Composition (2020/21)**

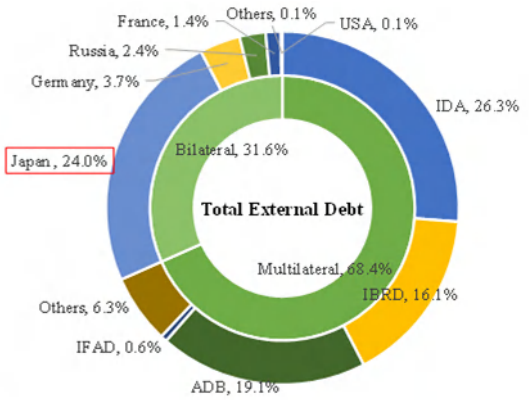



Source: MoF

**Figure 21-4: Redemption Profile of Public Debt**

### 3) External Debit

Loans from multilateral institutions are long-term and largely on concessional terms. The International Development Association (IDA) continued accounting for bulk of the multilateral debt at US$ 22.2 billion as at end-March 2021. The debt from ADB grew to US$ 16.1 billion as at end-March 2021 from US$ 13.8 billion a year ago. Within bilateral debt, Japan continues to be the largest creditor to India, accounting for 24.0% at end-March 2021, followed by Germany, Russia, and France (Figure 21-5).



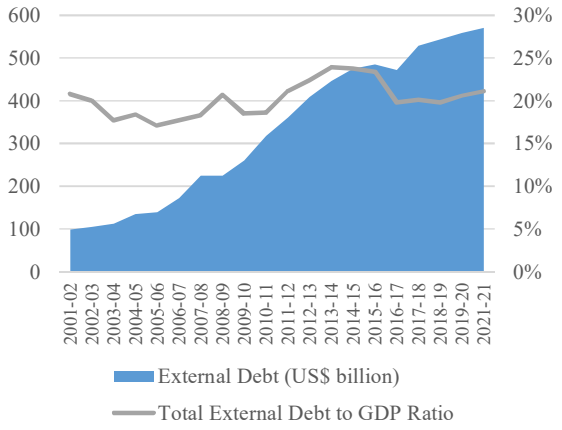

Source: MoF

**Figure 21-5: Outstanding External Debt by Creditor (2021)**

### 4) Outstanding External Debt Indicators

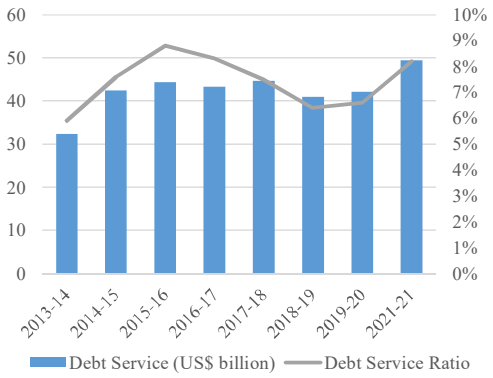
Taking external debt to GDP and the debt service ratio as important outstanding external debt indicators. External debt as a ratio to GDP rose marginally to 21.1% as at end-March 2021 from 20.6% a year ago (Figure 21-6). The debt service ratio rose to 8.2% during 2020-21 from 6.6% during the previous year mainly on account of, apart from lower current receipts, debt restructuring/debt reorganisation undertaken by leading Indian non-financial corporations. The debt service payment obligations arising out of the stock of external debt as at end March 2021 are projected to be moderate and peak in 2024-25 (Figure 21-7).

While the thresholds of both indicators of the GoI have not been confirmed, they are within the stable conditions if the standard threshold set by IMF; external debt to GDP ratio for 55% and debt service ratio for 15%, are followed.




Source: MoF

**Figure 21-6: Total External Debt to GDP Ratio**




Source: MoF

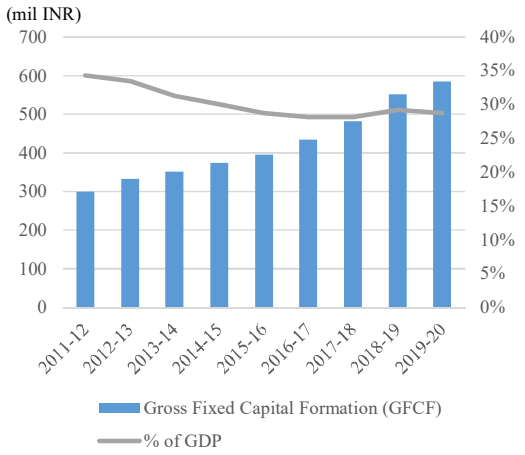
**Figure 21-7: Debt Service Ratio**

### 5) Gross Fixed Capital Formation

Gross fixed capital formation (GFCF), also called "investment", is defined as the acquisition of produced assets, including land improvements, plant, machinery, and equipment purchases; and the construction

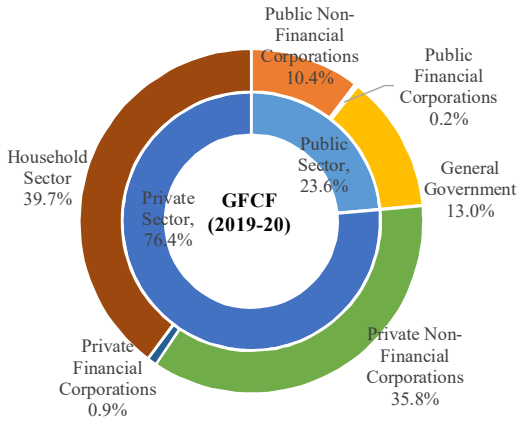
of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings. The indicator is important in determining the level of capital investment in the country.

Figure 21-8 and Figure 21-9 shows that India keeps the average 30% of GFCF in total GDP, which is higher than the average East and Southeast Asian countries. While the public sector contribution in GFCF is higher than the private sector in East and Southeast Asian countries, public sector components were about 24% and the private sector was about 76% in 2019-20 in India.




Source: MoF

**Figure 21-8: GFCF Trends in Current Prices**



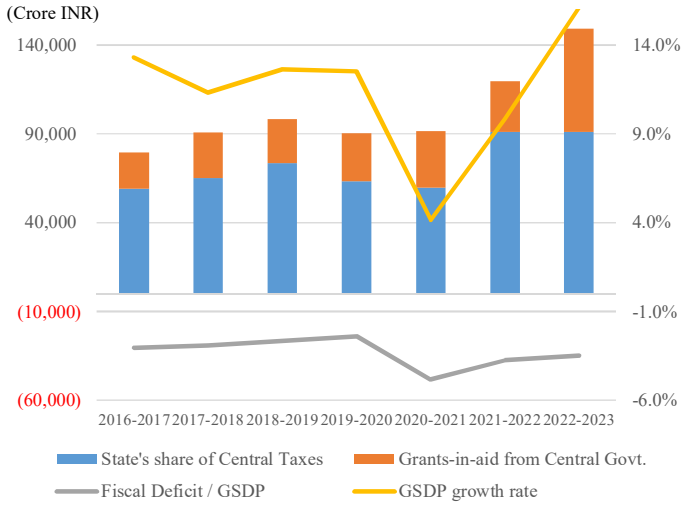

Source: MoF

**Figure 21-9: GFCF Breakdown (2019-20)**

### (2) State Government

In Bihar State, the Fiscal Deficit to Gross State Domestic Product (GSDP) has been maintained within the statutory limit of 3.5% as per Fiscal Responsibility and Budget Management (FRBM) Act. Bihar is one of those states which have taken its fiscal responsibility and implemented the FRBM Act. In the year 2022-23 it is likely to generate a revenue surplus and the fiscal deficit is likely to be contained at 3.47% of State GDP (within the FRBM limits of 3.5%). (Figure 21-10)

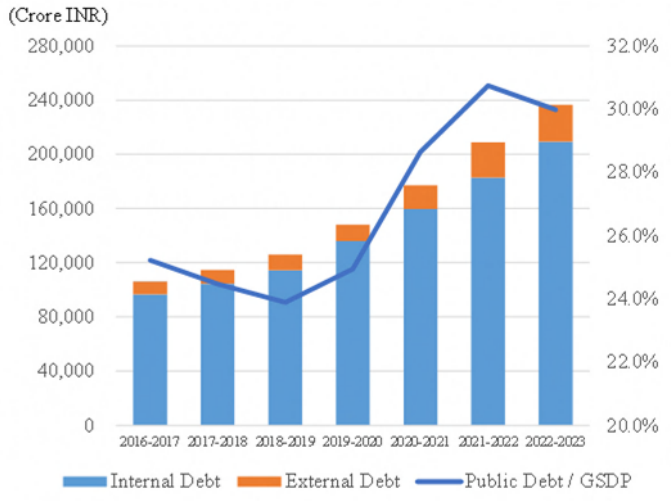
The contribution from the central government by taxes and grants will be expected to increase in 2021-22 and 2022-23. The GSDP growth rate did not show a negative figure even during the pandemic, and is expected to achieve 16% in 2022-23.




Source: Finance Department, GoB

**Figure 21-10: Debt Sustainability of Government of Bihar**

The Outstanding Public Debt is estimated at Rs. 2,38,126.69 crore in 2022-23 which is 31.95% of GSDP of Rs. 7,45,310.00 crore. Out of the total outstanding public debt, 88% are internal debt and 12% are external debt from the World Bank and ADB.




Source: Finance Department, GoB

**Figure 21-11: Public Debt of Government of Bihar**

### (3) Budget Allocation for PMRCL

The budget of MoHUA and the Government of Bihar (GoB) has been released to PMRCL shown in the following tables.

#### 1) MoHUA

The Ministry of Housing and Urban Affairs (MoHUA) is the nodal Ministry for the planning and coordination of Urban Transport matters at the central level. At the same time, technical planning of rail transport continues to be with the Ministry of Railways. Similarly, road transport is the responsibility of the Ministry of Road Transport and Highways, and major responsibility for urban transport infrastructure and service delivery rests with State Governments and local bodies.

The Metro Rail Policy, introduced in August 2017, acts as a guide to States and Union Territories for preparing comprehensive proposals for systematic planning and implementation of metro rail systems in the cities. At present, more than 700 km of metro rail lines are operational in 18 cities and about 1010 km of metro lines, including 82 km Delhi-Meerut RRTS corridor, are under construction in 27 cities which include Delhi and NCR, Mumbai, Kolkata, Bangalore, Chennai, Hyderabad, Nagpur, Ahmedabad, Gandhi Nagar, Pune, Navi Mumbai, Patna, Surat, Agra, Kanpur, Meerut, Bhopal and Indore (MoHUA Annual Report 2020-21).

Around 30-40 % of the total budget under MoHUA are budgeted for the metro projects (Table 21-1).

**Table 21-1: Budget Allocation for the MoHUA**

(in Rs. Crore)

| Year | Budget Estimated (BE) | Revised Budget (RE) | Provisional Expenditure | Budgeted for Metro | Budgeted for Metro (%) | Actual Expenditure for Metro | Utilized (%) |
|---|---|---|---|---|---|---|---|
| 2016-2017 | 24,523 | 32,550 | 22,871* | 10,000 | 31% | 15,727 | 157% |
| 2017-2018 | 40,618 | 40,754 | 30,610* | 18,000 | 44% | 13,978 | 78% |
| 2018-2019 | 41,765 | 42,965 | 40,731 | 15,000 | 35% | 14,470 | 96% |
| 2019-2020 | 48,032 | 42,267 | 31,732* | 19,152 | 45% | 18,908 | 99% |
| 2020-2021 | 50,040 | 46,791 | 28,110* | 20,000 | 43% | 9,000 | 45% |
| 2021-2022 | 54,581 | 73,850 | - | 23,500 | | - | - |

*: The amount is a provisional expenditure as of 31 December.

Source: Annual Report of MoHUA (2016 Independent Auditors Report To the Members of Patna Metro Rail Corporation Limited (2020 and 2021)

As of April 2022, the cumulative amount of Rs. 462.50 Crore has been released from MoHUA to PMRCL as part of the Government of India's share towards equity capital (Table 21-2). The equity share of the Government of India shown in the 2021-22 financial statement of PMRCL matches with the amount of Rs. 262.50 Crore. The additional Rs. 200.00 Crore will be reflected in the financial statement of 2022-23.

**Table 21-2: Fund Arranged by MoHUA**

(in Rs. Crore)

| Sl. | Funded portion by | Purpose | Date | Amount | Cumulative release |
|---|---|---|---|---|---|
| 1 | MoHUA | Share Equity | 19-Nov-2019 | 50.00 | 50.00 |
| 2 | MoHUA | Share Equity | 25-Jun-2020 | 100.00 | 150.00 |
| 3 | MoHUA | Share Equity | 12-Oct-2020 | 63.00 | 213.00 |
| 4 | MoHUA | Share Equity | 1-Oct-2021 | 49.50 | 262.50 |
| 5 | MoHUA | Share Equity | 27-Apr-2022 | 200.00 | 462.50 |

Source: MoHUA

### 2) Government of Bihar (GoB)

Until PMRCL was incorporated on 18th February 2019, there was no budget for Metro by GoB. The budget portion of the metro has been insignificant in the total budget of the Government of Bihar (Table 21-3).

**Table 21-3: Budget Allocation for the GoB**

(in Rs. Crore)

| Year | Total Budget of GoB | Total Expenditure against Budget | Budgeted for Metro | Budgeted for Metro (%) | Actual Expenditure for Metro | Utilized (%) |
|---|---|---|---|---|---|---|
| 2016-2017 | 154,327 | 126,302 | -* | -* | -* | - |
| 2017-2018 | 172,884 | 136,427 | -* | -* | -* | - |
| 2018-2019 | 190,919 | 154,655 | -* | -* | -* | - |
| 2019-2020 | 217,760 | 143,614 | 160.00 | 0.1% | 33.24 | 21% |
| 2020-2021 | 225,458 | 165,697 | 53.00 | 0.0% | 82.83 | 156% |
| 2021-2022 | 255,474 | Not yet | 1550.00 | 0.6% | 1057.585 | 60% |

* PMRCL was established in February 2019, so the information after 2019 is available.

Source: GoB

Based on the interview with PMRCL, the budget of GoB is released in stages. After the issuance of budget order by the Finance Department of GoB, Urban Development and Housing Department of GoB releases fund to PMRCL, however, there are some cases that the total budgeted amount is not released. For example, in 2021-22, out of the sanctioned budget of Rs. 1550 Crore, Rs. 1057.585 Crore was released with the following breakdown and table:

- Equity - Rs. 49.50 Crore + Rs. 200 Crore = Rs. 249.50 Crore
- Land - Rs. 308.085 Crore + Rs. 500 Crore = Rs. 808.085 Crore
- Total - Rs. 249.50 Crore + Rs. 808.085 Crore = Rs. 1057.585 Crore

**Table 21-4: Fund Arranged by GoB**

(in Rs. Crore)

| Sl. | Funded portion by | Purpose | Date | Amount | Cumulative release |
|---|---|---|---|---|---|
| 1 | GoB | Share Equity | 3-Sep-2019 | 3.00 | 3.00 |
| 2 | GoB | Share Equity | 24-Jul-2019 | 10.00 | 13.00 |
| 3 | GoB | Share Equity | 9-Feb-2019 | 50.00 | 63.00 |
| 4 | GoB | Share Equity | 14-Jan-2020 | 100.00 | 163.00 |
| 5 | GoB | Share Equity | 27-Aug-2020 | 50.00 | 213.00 |
| 6 | GoB | Share Equity | 21-May-2021 | 49.50 | 262.50 |
| 7 | GoB | Land Acquisition | 28-Dec-2021 | 308.09 | 570.59 |
| 8 | GoB | Share Equity | 20-Jan-2022 | 200.00 | 770.59 |
| 9 | GoB | Land Acquisition | 20-Jan-2022 | 500.00 | 1,270.59 |

Source: GoB

### 21.3.2 Financial Structure of PMRCL

Since PMRCL was established on 18th February 2019, the financial statements (The Profit Loss Statement (P/L), Balance Sheet (B/S), and Cash flow Statement (C/S)) were prepared for the three fiscal years:2019-20, 2020-21 and 2021-22. As PMRCL did not start its operations as of 31st March 2022, the financial statements did not show the regular working activities, however, they can be summarized as follows.

#### (1) Profit and Loss Statement

As PMRCL has not yet commenced its operations, PMRCL has no assets of plant and machinery. Office furniture, computer equipment, IT system, and software licenses are allocated to “depreciation” in P/L and “non-current assets” in B/S. Similarly, only “other income” composed of the interest income was allocated to the income, and there was no “revenue from operation”.

The entire staff at PMRCL was on deputation from the Central Government, State Government and outsourced. While the gross salary and allowances were paid directly to the deputed staff at PMRCL which was allocated to “employees benefit expenses”, employee benefit policy such as pension were not allocated to the “operating expenses”. The liabilities towards employee benefit lies with their parent organizations, thus PMRCL paid their contributions regularly to the parent organizations and they were allocated to the “other administrative expenses”.

**Table 21-5: Profit and Loss Statement of PMRCL (2019/20, 2020/21and 2021/22)**

| Particulars | 2019-20 | 2020-21 | 2021-22 |
|---|---|---|---|
| A. Income | Amount (Rs.) | Amount (Rs.) | Amount (Rs.) |
| 1. Revenue from Operation | 0 | 0 | 0 |
| 2. Other Income | 10,663,802 | 82,483,480 | 38,922,000 |
| **Total Income (A)** | **10,663,802** | **82,483,480** | **38,922,000** |
| B. Expenditure | | | |
| 1. Operating Expenses | | | |
| 2. Employees Benefits Expenses | | 158,669 | 17,132,000 |
| 3. Other Administratative Expenses | 8,760,772 | 14,963,146 | 18,862,000 |
| 4. Depreciation and Amortization Expenses | 410,567 | 680,061 | 725,000 |
| 5. Finance Cost | | | |
| **Total Expenditure (B)** | **9,171,339** | **15,801,876** | **36,719,000** |
| C. Profit/ (Losss) before exceptional and extra | 1,492,463 | 66,681,604 | 2,203,000 |
| Less: Preliminary Expenses write off | 5,112,566 | 20,450,265 | 9,178,000 |
| Profit/ (Loss) after exceptional and extraordina | -3,620,104 | 46,231,340 | -6,975,000 |
| D. Provision for tax | | | |
| (a) Current tax | | 13,042,961 | |
| (b) Tax adjustment in relation to prior years | | | 6,688,000 |
| (c) Deferred tax liability / (assets) | -57,415 | 7,936 | -75,000 |
| E. Profit / (Loss) from continuing operation | -3,562,689 | 33,180,443 | -13,588,000 |
| F. Profit / (Loss) from Discontinuing operation | | | |
| G. Profit / (loss) for the year | -3,562,689 | | -13,588,000 |
| **Total** | -3,562,689 | | -13,588,000 |
| Earning per equity share | | | |
| (1) Basic | -713 | 282,000 | -32,000 |
| (2) Diluted | -713 | 282,000 | -32,000 |

Source: Independent Auditors Report to the Members of Patna Metro Rail Corporation Limited

## (2) Balance Sheet

### 1) Equity Share Capital

PMRCL was incorporated with the authorized capital of Rs. 20 Crore with the equity share of Rs. 100 per share. PMRCL has been established as a 50:50 joint venture of the GoI and the GoB. As of 31st March 2022, the equity share capital has been increased to Rs. 525 Crore with the same shared capital structure. The transition of the equity share capital by GoI and GoB is shown in Table 21-6.

**Table 21-6: Equity Share Capital by GoI and GoB**

(in Rs. Crore)

| Period | GoI | GoB | Total |
|---|---|---|---|
| 2020/3/31 | 0.00 | 0.05 | 0.05 |
| 2021/3/31 | 213.00 | 213.00 | 426.00 |
| 2022/3/31 | 262.50 | 262.50 | 525.00 |

Source: Financial Statement of PMRCL

Based on the interview with PMRCL, the release of equity share capital by GoI and GoB has been processed as follows:

- After receipt of equity amount from GoB, the equal amount of equity is asked for from MoHUA. Since the formalities such as approval and transfer take time, the receipt of equity amount from GoI tends to be delayed.
- The equity received is first kept as "share application money" and shown in B/S under head "other equity".
- After receipt of equal equity from both sides, it is necessary to obtain the approval from the Board of Directors for utilization of "share application money" as well as to issue necessary share certificates in favour of GoI and GoB.
- If the approval of Board is received within the financial year, the amount of equity is shown in B/S of the same financial year under the head "equity share capital"

For example; in 2021-22, equity of Rs. 49.50 Crore is received from GoI and GoB, and also approved by Board, therefore, in B/S of 2021-22 Equity share capital is shown as Rs. 262.50 Crore from both GoI and GoB. Besides, GoB has also released Rs. 200 Crore as equity in 2021-22 but equal share from GoI is received in FY 2022-23 (23.05.2022), therefore, Board's approval could not be obtained in 2021-22 and accordingly, Rs. 200 Crore of GoB is shown as "share application money" under the head "other equity" in B/S of 2021-22.

### 2) Subordinate Debt

The interest free subordinate debts were received from GoB, for the purpose of land including R&R cost, the total of Rs. 808.085 Crore. The debts will be repayable only after all the outside debts (ODA) are repaid. Based on the interview with PMRCL, all of the debts have been disbursed as of August 2022 with the following breakdown:

- To District Land Officer/GoB - Approx. Rs. 741 Crore for acquisition of land and RR.
- Approx. Rs. 46 Crore to Indian Railways (East Central Railway) for crossing of Patna Metro under Patna and Patliputra Railway Stations.
- Approx. Rs. 22 Crore to National Highway Authority of India for making road over drainage etc.

**Table 21-7: Balance Sheet of PMRCL (2019/20, 2020/21and 2021/22)**

M/S, Patna Metro Rail Corporation Limited, Patna

| | Balance sheet as at 31st March' 2022 | Note no. | As on 31st Mar'20 | As on 31st Mar'21 | As on 31st Mar'22 |
|---|---|---|---|---|---|
| A | **Asset** | | | | |
| 1 | **Non-current assets** | | **808,339,077** | **2,255,182,121** | **11,677,251,000** |
| a) | Property, Plant & Equipment | 2 | 1,766,775 | 1,634,720 | 1,216,000 |
| B) | Capital work in progress | 3 | 784,224,000 | 2,251,652,056 | 11,671,646,000 |
| c) | Intangible Assets | 4 | 18,982 | 11,318 | 4,000 |
| d) | Financial Assets | | | | 0 |
| i) | Loan & Advances | 5 | 0 | 0 | 2,439,000 |
| ii) | Other Financial Assets | 6 | 1,821,640 | 1,821,640 | 1,822,000 |
| e) | Other Non-Current Assets | 7 | 20,450,265 | 12,908 | 0 |
| f) | Defferred Tax Assets (Net) | 8 | 57,415 | 49,479 | 124,000 |
| 2 | **Current Assets** | | **583,258,998** | **2,827,620,091** | **5,396,487,000** |
| a) | Financial Assets | | | | |
| i) | Trade Recievable | 9 | | | |
| ii) | Cash & cash equivalents | 10 | 492,468,354 | 1,993,604,640 | 3,479,606,000 |
| iii) | Other Bank Balances | 11 | | | 0 |
| iv) | Loans & Advances | 5 | 90,790,644 | 828,534,762 | 1,843,840,000 |
| v) | Other Financial Assets | 6 | | | 70,590,000 |
| b) | Other Current Assets | 7 | | | 4,000 |
| c) | Current Tax Assets (Net) | 12 | | 5,480,689 | 2,447,000 |
| | | **TOTAL** | **1,391,598,075** | **5,082,802,212** | **17,073,738,000** |
| B | **EQUITY AND LIABILITIES EQUITY** | | | | |
| 1 | **EQUITY** | | **1,096,937,311** | **4,289,617,754** | **7,266,029,000** |
| a) | Equity Share Capital | 13 | 500,000 | 4,260,000,000 | 5,250,000,000 |
| b) | Other Equity | 14 | 1,096,437,311 | 29,617,754 | 2,016,029,000 |
| | | | | | |
| | **LIABILITIES** | | **294,660,763** | **793,184,458** | **9,807,710,000** |
| 2 | **Non-Current Liabilities** | | **35,832,331** | **6,332,331** | **8,080,900,000** |
| a) | Financial liabilities | | | | |
| i) | Borrowings | 15 | 35,832,331 | 6,332,331 | 8,080,850,000 |
| ii) | Other Financial liabilities | 16 | | | 50,000 |
| b) | Provisions | 17 | | | |
| c) | Deferred Tax Liabilities (Net) | 8 | | | |
| 3 | **Current Liabilitites** | | **258,828,432** | **786,852,127** | **1,726,810,000** |
| a) | Financial liabilities | | | | |
| i) | Trade Payable | 18 | | | |
| ii) | Other Financial liabilities | 16 | | | 421,162,000 |
| b | Other Current Liabilities | 19 | | 13,042,961 | 0 |
| c) | Provisions | 17 | 258,828,432 | 773,809,166 | 1,305,648,000 |
| | | **TOTAL** | **1,391,598,075** | **5,082,802,212** | **17,073,739,000** |

Source: Independent Auditors Report To the Members of Patna Metro Rail Corporation Limited

### (3) Cash Flow Statement

The cash flow statement of 2021-22 shows that the net cash from operating activities and investment activities were negative due to expenditure such as “capital work in progress”, however, with the positive value of net cash from financing activities, cash & cash equivalent at the end of the year showed the positive values. This trend will likely to be continued until the operating revenue is generated.

**Table 21-8: Cash Flow Statement of PMRCL (2019/20, 2020/21and 2021/22)**

| | | 2020 | | 2021 | | 2022 | |
|---|---|---|---|---|---|---|---|
| **Cash Flows from Operating Activities** | | | | | | | |
| | Net Income | | -3,562,689 | | 33,180,443 | | -13,589,000 |
| **Add:** | **Expenses Not Requiring Cash** | | | | | | |
| | Depreciation | 410,567 | | 680,061 | | 725,000 | |
| | Income Tax | | | 13,042,961 | | | |
| | Differed Tax | -57,415 | | 7,936 | | -75,000 | |
| | Preliminary Expenses write off | - | | 20,450,265 | | 13,000 | |
| | Other | | **353,152** | | **34,181,223** | | **663,000** |
| **Add:** | **Decrease in Current Assets** | - | | - | | | |
| | Inventories | - | | - | | | |
| | Trade receivables | - | | - | | | |
| | Short-term loans and advances | - | | - | | | |
| | Other Current Assets | - | | - | | | |
| | Current Tax Assets | - | | - | | 3,034,000 | |
| | | | - | | - | | 3,034,000.00 |
| **Less :** | **Increase in Current Assets** | | | | | | |
| | Current Tax Assets | | | 5,480,689 | | | |
| | Short-term loans and advances | 361,158,644 | | 737,744,118 | | -1,015,305,000 | |
| | Trade receivable | | | | | | |
| | Security deposit | 1,821,640 | | | | | |
| | Other Financial Assets | | | | | -70,590,000 | |
| | Other current assets | 20,450,265 | | 12,908 | | 4,000 | |
| | | | **383,430,549** | | **743,237,715** | | **-1,085,891,000** |
| **Add:** | **Increase in Current Liability** | | | | | | |
| | Short term Borrowings | | | | | | |
| | Trade Payables | | | | | | |
| | Other Financial liabilities | | | | | 421,162,000 | |
| | Short-term provisions | 258,828,432 | | 514,980,734 | | 531,839,000 | |
| | | | **258,828,432** | | **514,980,734** | | **953,001,000** |
| **Less:** | **Decrease in Current Liabilities** | | | | | | |
| | Short Term Borrowings | | | | | | |
| | Trade payables | | | | | | |
| | Short Term Provision | | | | | | |
| | Short Term provisions | | | | | | |
| | Other current liabilities | | | | | -13,043,000 | |
| | | | **0** | | **0** | | **-13,043,000** |
| **Net Cash from Operating Activities** | | | **-127,811,653** | | **-160,895,316** | | **-155,825,000** |
| **Cash flows from Investing Activities** | | | | | | | |
| Add: | Sale of Fixed Assets | | | | | | |
| Less: | Purchase of new Equipment | | 2,196,324 | | 540,342 | | -299,000 |
| Less: | Capital work in progress | | 513,856,000 | | 1,467,428,056 | | -9,419,994,000 |
| Less: | Investments Increased | | 0 | | 0 | | -2,439,000 |
| | Other | | | | | | |
| **Net Cash used for Investing Activites** | | | **516,052,324** | | **1,467,968,398** | | **-9,422,732,000** |
| Add: | Share capital | | 500,000 | | 4,259,500,000 | | 990,000,000 |
| Add: | Share application Money | | 1,100,000,000 | | -1,100,000,000 | | 2,000,000,000 |
| Less: | Borrowing Repaid | | | | -29,500,000 | | -6,332,000 |
| Add: | Security deposit | | | | | | 50,000 |
| Add: | Long-term borrowings | | 35,832,331 | | | | 8,080,850,000 |
| **Net Cash from Financing Activities** | | | **1,136,332,331** | | **3,130,000,000** | | **11,064,568,000** |
| **NET INCREASE/DECREASE IN CASH** | | | 492,468,354 | | 1,501,136,286 | | 1,486,002,000 |
| **CASH & CASH EQUIPMENT AT THE BEGINNING OF YEAR** | | | | | 492,468,354 | | 1,993,604,640 |
| **CASH & CASH EQUIPMENT AT THE END OF THE YEAR** | | | **492,468,354** | | **1,993,604,640** | | **3,479,606,640** |

Source: Independent Auditors Report To the Members of Patna Metro Rail Corporation Limited

## (4) Funding of the Project

The total capital cost of the Patna Metro Rail Project is estimated to be INR 13,365.77 Crore, of which INR 5,520.93 Crore will be funded by the ODA loans from JICA as per the MoU signed on November 2019 between GoI, GoB and PMRCL (Table 21-9). The total cost will be revised during the Feasibility Study.

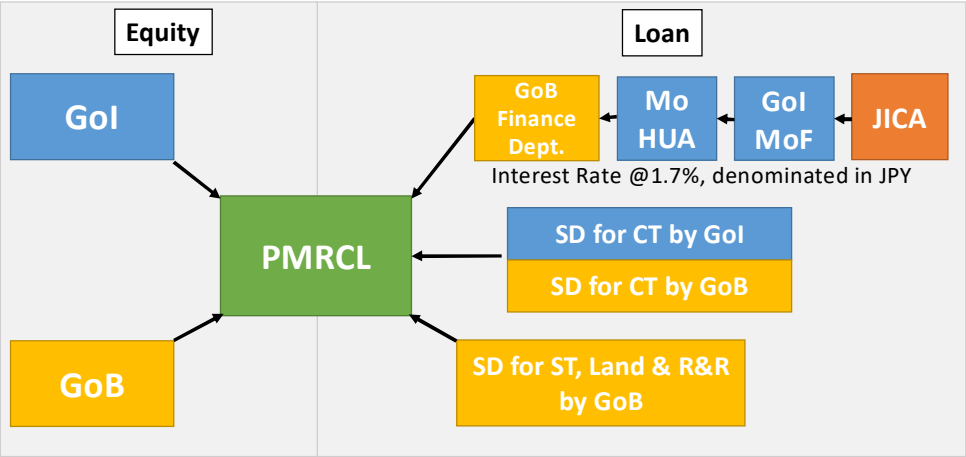
**Table 21-9: Total Cost of Patna Metro Rail Project**

| Sl. | Sources | Amount (Rs. Crore) | % |
|---|---|---|---|
| 1 | GoI Equity | 1,441.12 | 15.66% |
| 2 | GoI Subordinate Debt for CGST | 399.19 | 4.34% |
| 3 | GoB Equity | 1,441.12 | 15.66% |
| 4 | GoB Subordinate Debt for CGST | 399.19 | 4.64% |
| 5 | **Loan from bilateral/multilateral agencies** | **5,520.93** | 60.00% |
| 6 | Total cost excluding Land, R&R, PPP component | 9,201.55 | 100.00% |
| 7 | PPP component (AFC for stations) | 96.36 | |
| 8 | Total | 9,297.91 | |
| 9 | GoB Subordinate Debt for Land including R&R Cost | 3,401.66 | |
| 10 | Subordinate Debt for SGST to be borne by GoB | 645.48 | |
| 11 | IDC for loan and front end fee to be borne by GoB | 20.72 | |
| 12 | **Total Completion Cost** | **13,365.77** | |

Source: PMRCL Financial Statement 2021-22

The funding structure of the Project based on the interviews to Finance Department of GoB and PMRCL is shown in Figure 21-12.

- With an interest rate of 1.7%, the loan agreement will be made between JICA and the GoI, and it will be transferred to PMRCL through GoI MoF, MoHUA and GoB Finance Department. The charge will not be added during the transfer, and the fund will be denominated in JPY.
- The interest rate of Subordinate Debts from GoI and GoB is free. The debts will be repayable only after all the senior debts (JICA loan) are repaid.




Source: JST

**Figure 21-12: Funding Structure of Patna Metro Rail Project**

The conditions of the JICA loan will be estimated to be as follows:

- Interest rate: (main) 1.7%, (consulting services) 0.1%
- Repayment period: 30 years, Grace period: 10 years

The JICA loan is approximately around 759 million USD based on the exchange rate defined by JICA, and it will only compose 0.13% of the total outstanding external debt as of 31st March 2022. With the repayment period of 40 years including the grace period of 10 years, the annual debt service will be around 25 million USD, composes of only 0.05% of the total debt service as of 31st March 2022. Therefore, the impact of the JICA loan for the Patna Metro Construction Project to the debt sustainability of the Government of India will be significantly marginal.

The GoI and GoB are also providing sufficient funds to PMRCL to implement the Project in a timely manner, thus there will be less possibility that PMRCL will face issues of financial sustainability.

The table below is an updated funding pattern of this project based on the updated cost estimation. Though the debt share ratio of the central government has not been finalized yet, the base structure of the funding pattern will not change from this.

According to MoHUA, the funding arrangement for the Patna Metro Rail Project with the external financing agency (JICA) is on progress and is expected that the loan agreement will be signed by March, 2023. As on date, there is no plan of funding from any other financing agency.

**Table 21-10: Total Cost of Patna Metro Rail Project (draft)**

| Sl. | Sources | Amount (Rs. Crore) | % |
|---|---|---|---|
| 1 | GoI Equity | 1,441.12*1 | 11.1% |
| 2 | GoI Subordinate Debt for CGST | 399.19*1 | 3.1% |
| 3 | GoB Equity | 3,241.58 | 25.0% |
| 4 | GoB Subordinate Debt for CGST | 897.92*2 | 6.9% |
| 5 | **Loan from bilateral/multilateral agencies** | **7,005.75** | 54.00% |
| 6 | Total cost excluding Land, R&R, PPP component | 12,985.56 | 100.00% |
| 7 | PPP component (AFC for stations)*3 | 96.36 | |
| 8 | Total | 13,081.92 | |
| 9 | GoB Subordinate Debt for Land including R&R Cost | 2,892.01 | |
| 10 | Subordinate Debt for SGST to be borne by GoB | 784.46 | |
| 11 | IDC for loan and front-end fee to be borne by GoB | 502.58 | |
| 12 | **Total Completion Cost** | **17,260.97** | |

Note:
1* According to the PMRCL staff, the funding amount by the GoI is limited, 1,841 Crore Rs. including GST and SD. Other than this amount will be covered by the state government (GoB).
2* The ratio of equity and CGST of GoI is 27.7% so the same ratio is assumed to apply.
3* The PPP component is the same as the amount shown in the DPR.

Source: Prepared by JST based on the assumptions in the DPR.

## 21.4 Project Evaluation Indicators

### 21.4.1 Quantitative Evaluation Indicators

#### (1) Indicators related to Train Operations

The expected quantitative evaluation indicators and the source of data are listed in the following table as per the request from the JICA guideline.

**Table 21-11: Quantitative Evaluation Indicators (Train Operations)**

| # | Indicators | Corridor | 2028 | 2030 | 2031 | 2041 | 2051 |
|---|---|---|---|---|---|---|---|
| 1 | Operation rate (%/year) | Both corridors | 92% | | - | - | - |
| 2 | Car-km (thousand-train km/day) | Corridor 1 | 19.1 | 19.1 | 39.1 | 41.0 | 46.4 |
| | | Corridor 2 | 13.5 | 13.5 | 17.0 | 18.1 | 20.9 |
| 3 | Car-km of women-only cars (thousand km/day) | Corridor 1 | 5.7 | 5.7 | 7.0 | 6.8 | 7.7 |
| | | Corridor 2 | 4.5 | 4.5 | 5.7 | 6.0 | 7.0 |
| 4 | Transportation volume (million passenger km/day) | Corridor 1 | 3.0 | 3.5 | 3.7 | 4.3 | 5.4 |
| | | Corridor 2 | 1.6 | 1.7 | 1.8 | 1.9 | 2.1 |
| 5 | Number of trains (train/day) | Corridor 1 (3 cars) | 145.6 | 145.6 | 26.8 | 0 | 0 |
| | | Corridor 1 (6 cars) | 20.4 | 20.4 | 177.2 | 200 | 226 |
| | | Corridor 2 (3 cars) | 166 | 166 | 208 | 222 | 256 |
| | | Corridor 2 (6 cars) | 0 | 0 | 0 | 0 | 0 |
| 6 | Number of passengers (thousand pax/day) | Corridor 1 | 467 | 534 | 568 | 656 | 829 |
| | | Corridor 2 | 245 | 267 | 278 | 293 | 327 |
| 7 | Farebox revenue (million Rs./day) | Both corridors | 23.1 | 26.3 | 31.8 | 78.5 | 169.7 |

Source: JST

The source of each indicator is shown as follows.

1. Operation rate: Train Operation Plan
2. Car kilometer: Train Operation Plan
3. Car kilometer of women-only cars: Train Operation Plan
4. Transportation volume: Demand Forecast
5. Number of train operations: Train Operation Plan
6. Number of passengers: Demand Forecast
7. Farebox revenue: Financial Analysis

#### (2) Indicators related to GHG Emissions

The reduction of the $CO_2$ emission by MRT is calculated by the JICA Climate FIT Tool, and the results are shown below.

**Table 21-12: Quantitative Evaluation Indicators ($CO_2$ emission, PT60)**

(Unit, $tCO_2$/year)

| | 2028 | 2030 | 2031 | 2041 | 2051 |
|---|---|---|---|---|---|
| Emission reduction | 64,968 | 72,802 | 74,214 | 134,047 | 191,467 |
| Baseline emission | 107,581 | 123,530 | 128,999 | 190,445 | 252,078 |
| Project emission | 42,613 | 50,728 | 54,785 | 56,398 | 60,611 |

Source: Calculated by JICA Climate FIT

In 2028, the emission reduction is not so large but the saved emission with the project will be gradually bigger year by year due to the progress of the modal shift from road transport to MRT.

### 21.4.2 Qualitative Evaluation Indicators

Development of new high capacity, high-frequency public metro system from Danapur to Khemni Chak and Patna Station to New ISBT corridors have a potential to cater for existing and future passenger demand and will relieve congestion on the road and the existing public transport network. Besides, the Project will significantly benefit the environment and economy directly and indirectly. The project will, therefore, be beneficial to the population in the Project area.

The expected qualitative evaluation indicators are as follows:

**Table 21-13: Qualitative Evaluation Indicators**

| Indicators | Details |
|---|---|
| Improvement of traffic conditions in Patna | During the SIA Survey, many respondents living along the corridor complained about the traffic conditions in Patna. Some school teachers responded that the metro rail will reduce road traffic and traffic accidents, and students can reach eithers to school or their home safely. Some respondents experienced fatigue due to traffic jam and noise pollution created due to uncontrolled honking.<br>The Project will significantly improve the city's public transport network and contribute to mitigate environment, health hazards, climate change impact and safety problems. |
| Mitigation of environmental problems | |
| Mitigation of health hazards | |
| Mitigation of climate change impact | |
| Mitigation of safety problems | |
| Enhancement of local economy | During the SIA Survey, the respondents expressed their willingness for job opportunities during construction and operation of the Project. The direct employment to be hired by PMRCL during construction and operation, and indirect employment in the commercial and residential area at TOD sites will be expected. Moreover, the implementation of the Project will offer more equitable access to transport choices for passengers wishing to access employment, education or commercial facilities, and this will contribute to the enhancement of the local economy. |
| Direct and indirect employment creation during construction and operation | |
| Social and economic impact including gender equality and poverty reduction | Several measurements for gender equality are already implemented at Delhi Metro, and the same is expected to be applied in Patna Metro:<br>- Introduction of women-only cars (Figure 21-13)<br>Delhi Metro was the first in India to introduce all-day women-only cars, and they will give comfort for women to travel without safety concerns.<br>- Consideration to encourage use by female passengers<br>Delhi Metro introduced an anti-disruptive behaviour surveillance cameras in each train car and deployed security personnel in the station. Escalators have a sari guard feature that deflects loose clothing from getting trapped.<br>- Active Employment of Female Staff (Figure 21-14)<br>Delhi Metro is taking the initiative in hiring female employees for promoting women employment in society. |
| Symbol of Japan – India cooperation | It is widely known that the Delhi Metro was constructed with the Japanese assistance, and the people of Delhi recognize that "Delhi Metro is the result of Japanese hardware and software assistance" (Figure 21-15). The same effect will be expected in Patna. |

Source: JST



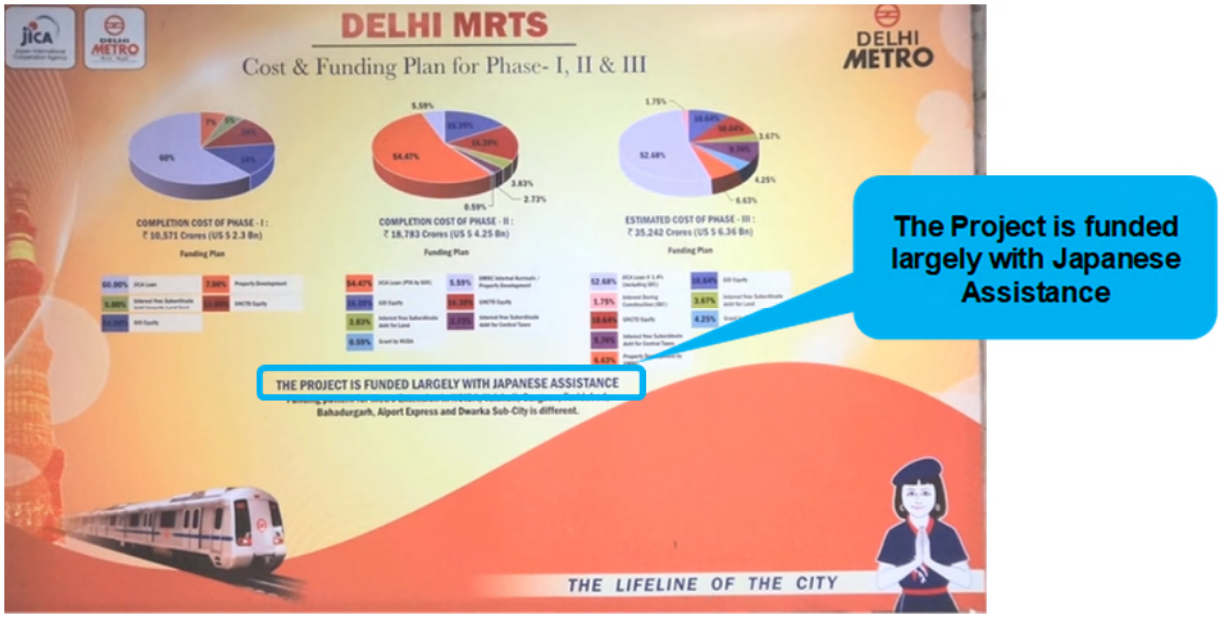
Source: Presentation on "Delhi Metro Urban Rail Construction Project (Phase 1/2/3)", prepared by Dr Reiko Abe, Oriental Consultants Global

**Figure 21-13: Women Only Car at Delhi Metro**



Source: Presentation on "Delhi Metro Urban Rail Construction Project (Phase 1/2/3)", prepared by Dr Reiko Abe, Oriental Consultants Global

**Figure 21-14: Woman Employee at DMRC**




Source: Presentation on "Delhi Metro Urban Rail Construction Project (Phase 1/2/3)", prepared by Dr Reiko Abe, Oriental Consultants Global

**Figure 21-15: Station Area Signage at Delhi Metro**

# 22. Economic Analysis

## 22.1 Overview of Existing Studies (N/A)

## 22.2 Reviews of Existing Studies and Proposals for Improvement (N/A)

## 22.3 Quality of Life (QOL) Indicators

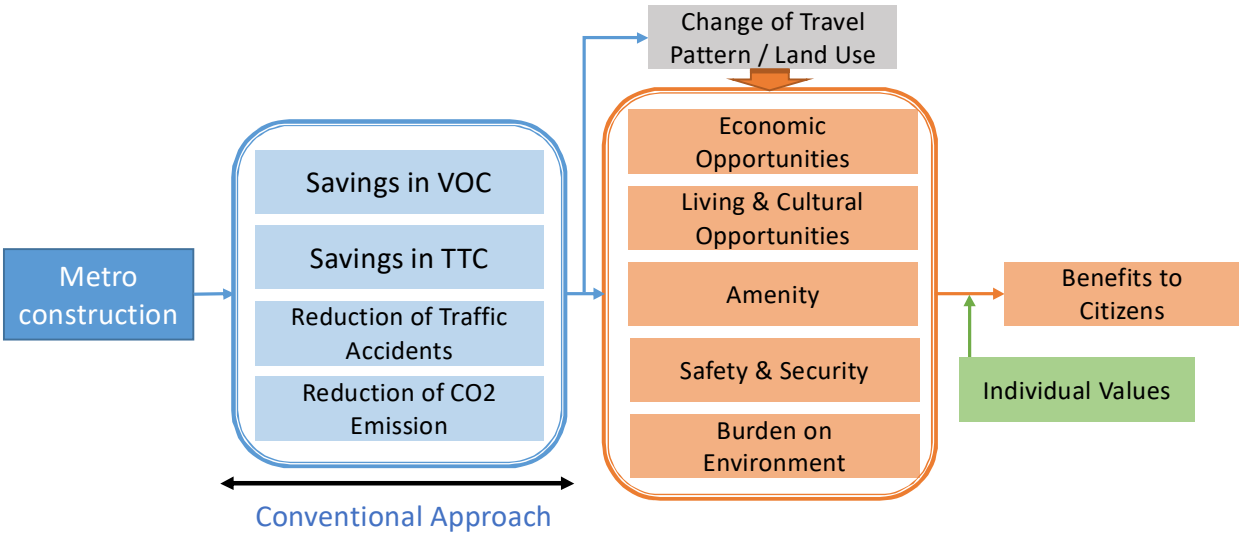
Besides the above conventional evaluation methods, JST has conducted the QOL analysis in this Survey.

### 22.3.1 Concept of QOL Analysis

#### (1) Conventional Economic Benefits and QOL Indicators

The QOL approach is to estimate the changes in QOL indicators through the construction of a metro system by different attributes and verify the effects through improving the accessibility of QOL indicators. Professor Yoshitsugu Hayashi of Chubu University and others have published several research papers focusing on the methodologies of QOL indicators such as "Development of QOL-based Project Evaluation Methodology and Evaluation of Contribution to the SDGs" and "QOL Method for Appraisal of Transport Facilities: Theory, Case Studies, and Implications to Indian HSR".

The conventional economic benefits of transport project evaluation generally consist of four items: savings in VOC (Vehicle Operating Cost), savings in TTC (Travel Time Cost), reduction of traffic accidents and reduction of $CO_2$ emission, and they are generated by transport projects. On the other hand, the QOL-based project evaluation focuses on the benefits to citizens, by reflecting conventional benefits and individual values through the changes of travel patterns or land use after the metro construction. The major individual values consist of 1) economic opportunities, 2) living and cultural opportunities, 3) amenity, 4) safety and security, and 5) burden on environment (Figure 22-1).




Source: JST based on the QOL Accessibility Project Evaluation Manual by Dr Hayashi

**Figure 22-1: Relationship between Conventional Economic Benefits and QOL Evaluation Indicators**

This approach will be able to evaluate the positive impact of transport projects through improving the level of QOL, and these QOL indicators can capture the change of values and the impacts of transport infrastructure investment to contribute to the SDGs goals, especially Goal 11 (Sustainable Living) and Goal 16 (Inclusiveness).

### 22.3.2 QOL Survey Outline

Based on the above QOL concept, JST has conducted the QOL survey as part of the SIA survey to a total of 240 respondents at 24 stations (10 respondents at each station with the gender equality of five males and five females). The interviews were conducted through survey of the local people to collect social and economic information, their QOL and to know the opinion of respondents and their expectation from the metro project. The Questionnaire included the following items:

- Household structure, income and expenditure
- Access to social services (office, school, hospital, shopping centre, etc.)
- Current satisfaction level of QOL (access to bus stop, office, school, hospital, shopping centre, housing conditions, traffic safety, green environment, air pollution, noise, etc.)
- Importance of QOL items (transport, job opportunities, education, health/medical care, shopping, amusement / travel, housing conditions, traffic safety, green environment, air pollution, noise, etc.)

The satisfaction and importance of QOL items are categorized into five: 1) economic opportunity, 2) living and cultural opportunity, 3) amenity, 4) safety and security and 5) burden on environment (Table 22-1).

**Table 22-1: Category of QOL Items**

| Category | Satisfaction | Importance |
|---|---|---|
| Economic Opportunity | Access to bus stop | Transport |
| | Access to office | Job opportunities |
| Living & Cultural Opportunity | Access to school | Education |
| | Access to hospital/clinic | Health / medical care |
| | Access to shopping centre | Shopping |
| Amenity | Access to movie theatre | Amusement / travel |
| | Overall housing conditions | Housing conditions |
| Safety & Security | Traffic safety | Traffic safety |
| Burden on Environment | Green environment | Green environment |
| | Air pollution | Clean air |
| | Noise | Silent environment |

Source: JST




Source: JST

**Figure 22-2: Survey Locations**



Source: JST

**Figure 22-3: Photos during Interview Survey**

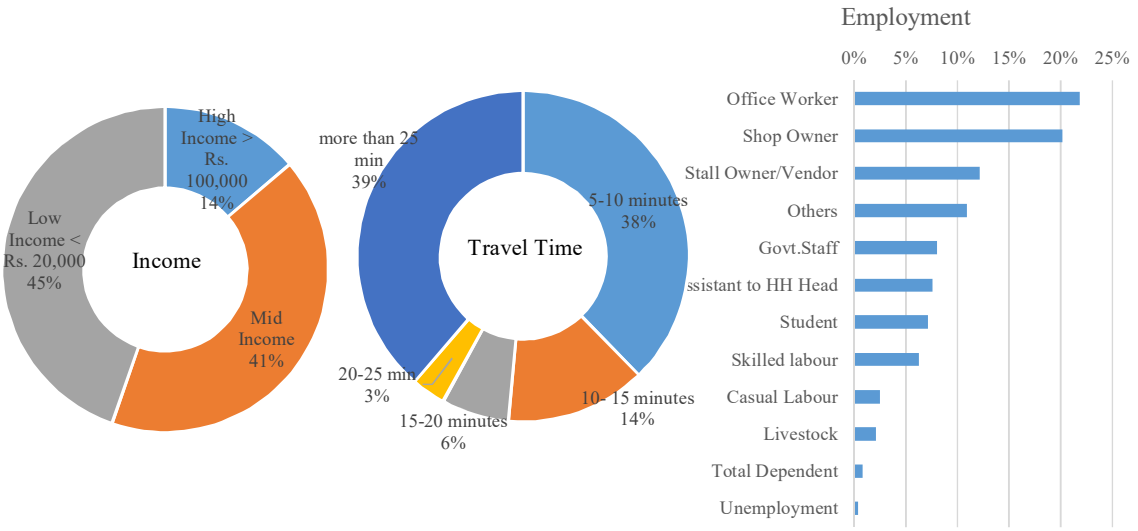
### 22.3.3 Observations

#### (1) Attributes of Respondents

The attributes of respondents showed that the low income level of less than Rs. 20,000 monthly accounted for a majority of the share (45%), followed by the middle income level (41%) and the high income group of more than Rs. 100,000 monthly (14%) (Figure 22-4). The income share is in line with the figure shown in the "Bihar Economic Survey 2021-22" that the state domestic product per capita income of Bihar at current prices was Rs. 46,292.

The travel time from home to office or school showed that 39% of respondents' travel time was more than 25 minutes, and 38% was 5-10 minutes.

With regard to employment, the office worker showed the largest share (22%), followed by shop owner (20%) and stall owner/vendor (12%). Some students were also interviewed.




Source: JST

**Figure 22-4: Attributes of Respondents**

### (2) Qualitative Impact of the Project

The respondents were asked for their awareness / opinion about the proposed Project, and the qualitative impacts of the Project were found as follows:

- It was observed that most of the respondents had positive response towards the Project.
- According to their opinion, the city is facing the problem of heavy traffic congestion, noise pollution due to continuous vehicular movement and honking, vehicular pollution, road accidents due to heavy traffic.
- Respondents are positive about the metro fare as the auto drivers' fare are not fixed and they demand high fare rates. With the Metro project, the rates for travelling will be fixed and affordable.
- Respondents are expecting job opportunities in the Metro project during the construction and operational phase

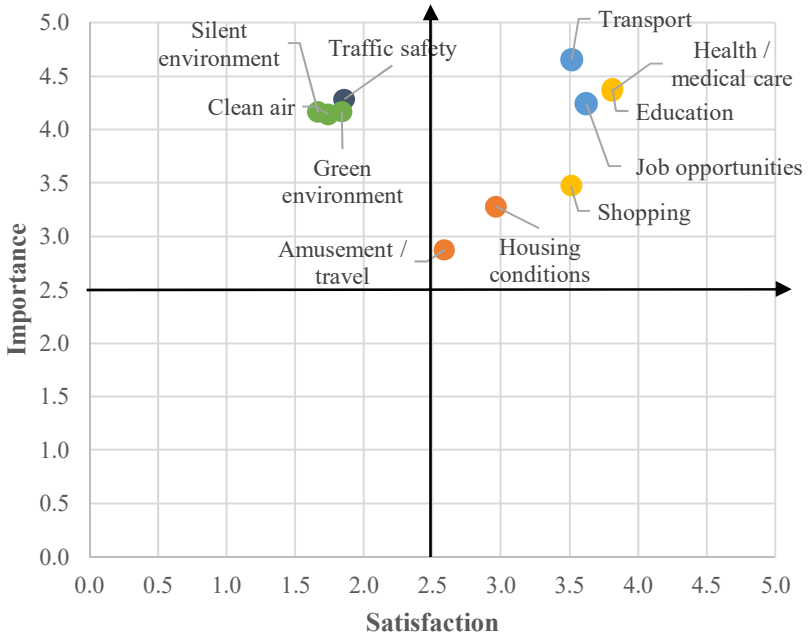
The project is expected to improve the QOL indicators of respondents through the improvement of transport conditions in the City.

## 22.3.4 Results

### (1) Satisfaction and Importance of QOL Factors

With the interview results of satisfaction level and importance of QOL items, it is observed that the satisfaction towards access to economic, living, cultural and amenity opportunities showed higher score. However, people are highly unsatisfied towards the parameters such as Traffic Safety, Green Environment, Air Pollution and Noise Pollution while they are considered as important QOL items (Figure 22-5).

The results showed that safety, security and burden on the environment are the major challenges that people in Patna are facing.




Source: JST

**Figure 22-5: Satisfaction and Importance of QOL Factors**

### (2) Overall QOL Estimation

Due to the constraints on the number of samples and deficiencies in the quality of data, a simplified model was adapted to calculate the overall QOL with the following formula and steps:.

$$QOL^t = \sum_m S_m^t \cdot W_m^t$$

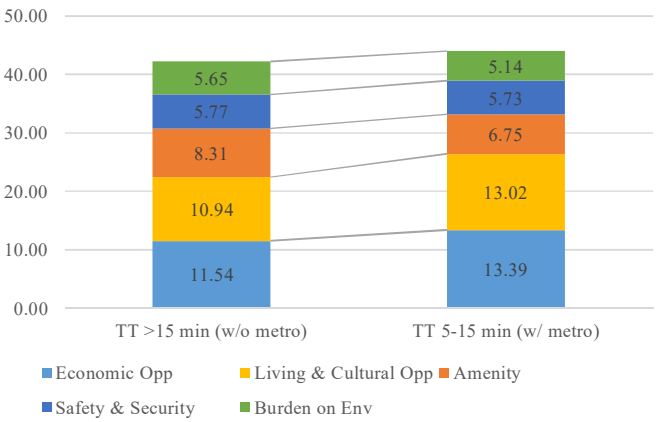
Where, t = travel time of each respondent
m = QOL factor
S = Satisfaction of QOL factor
W = Weight of QOL factor

i) QOL satisfaction level (1-5) is multiplied by QOL importance level (1-5) as a weight
ii) QOL items are grouped into five factors: 1) economic opportunity, 2) living and cultural opportunity, 3) amenity, 4) safety and security and 5) burden on environment
iii) Each group is weighted as 20 points in total of 100 points

The accessible value of travel time and the perceived value of QOL for individuals were used in the analysis. The individual QOL was divided into two groups with the travel time of i) less than 15 minutes and ii) more than 15 minutes, by referring to the estimated average travel time of metro of 14 minutes, as estimated in the demand forecast. By assuming the category of less than 15 minutes as “with metro” and more than 15 minutes as “without metro”, the overall QOL was higher with shorter travel time (with metro), especially indicators related to economic, living and cultural opportunities (Figure 22-6).

As for indicators such as amenity, safety and security, and burden on environment, scores of longer travel time were better than scores of shorter time, indicating a selection of better environment conditions to those who are living outside the city centre. The Patna Metro Rail Construction Project would bring positive impact on these environmental issues, and the QOL environment indicators of those who are living close to the city centre are also expected to be improved.

It was ideal to analyze the QOL by conducting a questionnaire survey of several thousand people with different attributes such as income group and gender. However the number of samples was not sufficient to show significant results because this survey was a simple survey targeting 240 people at 24 stations on a trial basis within the scope of the subcontracted EIA and SIA survey.




Source: JST

**Figure 22-6: QOL Estimation**

### (3) Further Improvement of the QOL Analysis

As the QOL analysis applied in this Survey was conducted as an experimental case, several improvements can be recommended during the monitoring period.

i) Number of samples

While the number of samples in the Survey was only 240, it is expected to collect a few thousand samples in order to accomplish significant results. Utilization of online surveys would be an option to increase the number of samples.

ii) Questionnaire structure

A simplified questionnaire was applied in this Survey, and the weight of QOL items were calculated based on the importance of QOL items. For conducting a more comprehensive survey, conjoint analysis in which respondents select the profile they find most desirable from multiple profiles would be recommended. The inclusion of monetary values in the choices would make it possible to convert the weights into monetary values.

## 22.3.5 QOL Monitoring and Customer Satisfaction Survey

Monitoring QOL indicators and conducting Customer Satisfaction Survey for metro passengers during project implementation is recommended to verify the effectiveness of the Project. The purpose of QOL monitoring is to measure the impacts of the Project to the citizens, and the customer satisfaction survey is to receive feedback from passengers to improve the quality of services.

During the implementation, PMRCL is expected to be responsible for monitoring through the annual survey. DMRC has experiences of conducting a customer satisfaction survey since 2013, and their survey method would be a considerable reference to PMRCL.




Source: https://www.zonkafeedback.com/blog/dmrc-customer-satisfaction-survey

**Figure 22-7: DMRC Customer Satisfaction Survey**

Although DMRC responded that they could not disclose the methodology of the customer satisfaction survey as it is confidential information, customer satisfaction surveys of urban transit users are conducted in various cities, especially in Europe, where urban transit systems are operated under public service contracts between city transit authorities and private operators. In Europe, in particular, some cities apply an incentive system in which the results of the customer satisfaction survey are reflected in the contract amount of the operator. Possible evaluation items include the followings:

**Table 22-2: PMRCL Customer Satisfaction Survey Evaluation Items (Draft)**

| | |
|---|---|
| **Availability** | Frequency, operation time, timeliness of departures |
| **Accessibility** | Station location, connectivity with other modes of transport |
| **Affordability** | Fare level |
| **Facilities** | Cleanliness of the train interior, air conditioning inside the train |
| **Information** | Easy-to-understand information and announcements |
| **Customer service** | Friendly and courteous staff, response to complaints |
| **Safety** | Convenience of women-only cars, security in the train/station |
| **Environment impact** | Noise and vibration inside the train |

Source: JST

While the customer satisfaction survey to be conducted by PMRCL does not involve financial incentives, it is expected that the survey will be conducted on a regular basis to analyze the causes of trend changes in evaluation items with low/high scores and to improve service levels.

The main questionnaire in the surveys are listed in Table 22-3.

**Table 22-3: Overview of QOL Monitoring and Customer Satisfaction Survey**

| | |
|---|---|
| **Target** | A few thousand passengers using Patna Metro |
| **Frequency** | Once a year |
| **Method** | Online and household interview survey |
| **QOL Indicators** | • Household income and expenditure<br>• Access to social services (office, school, hospital, shopping centre, etc.)<br>• Current satisfaction level of QOL (access to bus stop, office, school, hospital, shopping centre, housing conditions, traffic safety, green environment, air pollution, noise, etc.)<br>• Importance of QOL items |

| | |
|---|---|
| **Customer Satisfaction Survey** | Satisfaction level of metro (availability, accessibility, affordability, facilities, information, customer service, security, safety including women only cars, environment impact) |

Source: JST

## 22.4 Clean Development Mechanism (CDM)

### 22.4.1 What is CDM?

The Clean Development Mechanism (CDM) is a system that supports efforts to reduce $CO_2$ emissions implemented by developing countries with funds and technology from developed countries and shares the benefits caused by achieved emission reduction between both countries. It is one of the "Kyoto Mechanisms" included in the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC) and is stipulated in Article 12 of the Kyoto Protocol.

In 2016, the Paris Agreement, a new framework replacing the Kyoto Protocol for GHG emission reductions from 2020, was adopted at COP21 in Paris. The new framework has set a long-term common global goal for holding the increase in the global average temperature to well below 2 degrees above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5 degrees above pre-industrial levels[61].

### 22.4.2 Activities in Delhi Metro

In 2007, DMRC was the world's first railway and metro operator to be approved for inclusion in the CDM list by the United Nations. DMRC has sold 4.41 million carbon credits since 2007 through the activities listed below.

**Table 22-4: CDM conducted by DMRC**

| Project No. | Contents | Amount of Reduced $CO_2$ | Calculation Period | Issuance Institute |
|---|---|---|---|---|
| Project No. 1351 | Installation of low GHG emitting rolling stock in Metro System | 541,613 | 2007-2017 | UNFCCC |
| Project No. 4463 | Modal shift | 3,835,703 | 2011-2018 | UNFCCC |
| ID.GS1246, ID.GS4636 ID.GS5204 | Energy Efficiency measures | 15,999 | 2012 - current | Gold Standard |
| Project No. 9863 | MRTS PoA (Programme of Acitieis) Project | - | - | UNFCCC |
| | DMRC Solar PV Project | 18,437 | - 2018 | UNFCCC |

UNFCCC: United Nations Framework Convention on Climate Change

Source: Interview with DMRC staff and DMRC website[62]

Based on the interview with DMRC, the first project, “Installation of low GHG emitting rolling stock in the metro system,” was traded with JCF (Japan Carbon Finance). The other projects are traded with the international carbon market; the carbon prices fluctuate over the years. Due to high demands for carbon products, carbon prices are not expected to decrease over the years unless a big financial crisis happens.

Regarding the latest information, the traded value in 2020 was 20 million carbon credits with 3.5 million

[61] https://www.mofa.go.jp/ic/ch/page1we_000102.html
[62] https://www.delhimetrorail.com/pages/en/corporate/clean-development-mechanism

INR (0.175 INR/ carbon credit), which is reported in the annual report of DMRC as shown below.

DMRC has sold the credit by itself to interested international parties. Also, if the project is registered for PoA, the credit is traded directly to international interested parties.

**Table 22-5: Carbon Emission Reduced Units in 2020-2021**

(₹ in Lakhs)

| Position as at | Carbon Emmision Reduction (CER) Units | | | |
|---|---|---|---|---|
| | 2020-21 | | 2019-20 | |
| Particulars | Quantity (Units) | Amount | Quantity (Units) | Amount |
| Opening Balance | 3337930 | 450.27 | 2156644 | 257.42 |
| Purchase / (Transfer) | 223172 | 41.48 | 1181286 | 192.85 |
| Sale / Lease | 15000 | 6.55 | - | - |
| Closing Balance | 3546102 | 485.21 | 3337930 | 450.27 |

Source: Annual Report 2020-2021, Delhi Metro

According to DMRC staff, the transaction of DMRC had been conducted based on the Kyoto Protocol, which expired in 2020, and is in a transition period for the Paris Agreement signed in 2015 at COP21. As a result, it is possible to apply for CDM, but new projects will be registered as "provisional registration". It is unclear about the Paris Agreement methodology, but not many changes are assumed as the methodologies are well established.

### 22.4.3 Applicability in Patna Metro

Through the interview with DMRC staff, possible CDM approaches to Patna Metro are assessed as follows. As explained, Project No. 1351 has already been applied for a new metro project since the activity is already in the PoA (Programme of Activities) Project. Also, energy efficiency projects require "before" and "after" indicators. Therefore, it is not possible to apply through a green-field project. Other projects have already been or will be considered by PMRCL with support from DMRC.

Credits earned through the Patna Metro Rail Project will be provided by DMRC who is the registered authority of this activity.

**Table 22-6: Applicability of CDM Projects for Patna Metro**

| Project No. | Contents | Applicability for Patna Metro |
|---|---|---|
| Project No. 1351 | Installation of low GHG emitting rolling stock in Metro System | • The technology is applied to the rolling stock of Patna Metro.<br>• While it is registered as a "new technology" for DMRC, it has been applied in other metro projects, so the emission reduction is already included in the PoA project. |
| Project No. 4463 | Modal shift | • In DMRC, the modal shift project has been the most profitable; while it expired in 2018, the new baseline data was obtained after the COVID and will start again. |
| ID.GS1246, ID.GS4636 ID.GS5204 | Energy Efficiency measures | • There are two possible projects; LED Lighting at Station and Variable Voltage Variable Frequency Drive.<br>• The two projects are related to energy efficiency, requiring "before" and "after" indicators. As the Patna Metro is a green-field project, it is not possible to measure the comparison of "before" and "after" indicators. |
| Project No. 9863 | MRTS PoA Project | • DMRC can provide consultancy services to Patna Metro for CDM registration on a fee basis, including applying PoA (Programme of Activities).<br>• After issuing the LOA to DMRC by Patna Metro, approximately 6-8 months will be required to complete the assignment. |

| Project No. | Contents | Applicability for Patna Metro |
|---|---|---|
| | DMRC Solar PV Project | • It is possible to apply this to the Patna Metro Construction Project.<br>• As per Patna Metro DPR, the expected peak solar power generation of 50 kwp for each elevated station and 2000 kwp for the maintenance depot is considered. Therefore, a total of 2.6 mwp from solar is planned as there are 12 elevated stations and one depot in Patna metro.<br>• Considering 100-120 w/sqm of solar generation, the required area of a solar panel is approximately 2166-2600 sqm. |

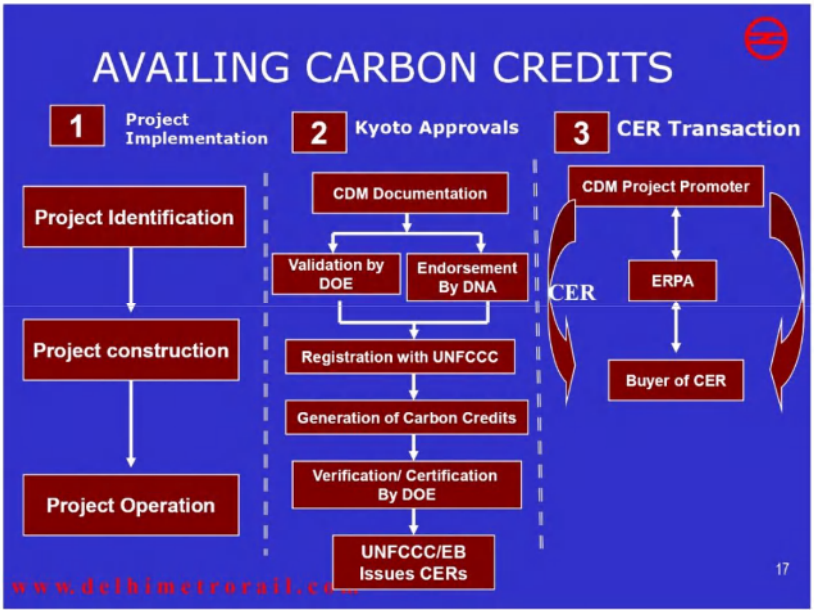
Source: Interview with DMRC and PMRCL

In order to register of the PoA of United Nations Framework Convention on Climate Change (UNFCCC), the PMRCL has to engage as a consultant of DMRC according to DMRC staff. The flow chart below illustrates how to avail carbon credits through metro projects.

Currently, three metro projects registered their carbon credits by way of DMRC, and the predicted emission amount per annum is shown below.

1. Ahmedabad Metro Phase 1: 138,812 $CO_2$ eq. per year
2. Mumbai Metro: 261,968 ton $CO_2$ eq. per year
3. Chennai Metro: 568,495 ton $CO_2$ eq. per year

In addition to these, Ahmedabad Metro Phase 2 and Surat Metro (Gujarat State) are currently under the registration process.




Source: DMRC

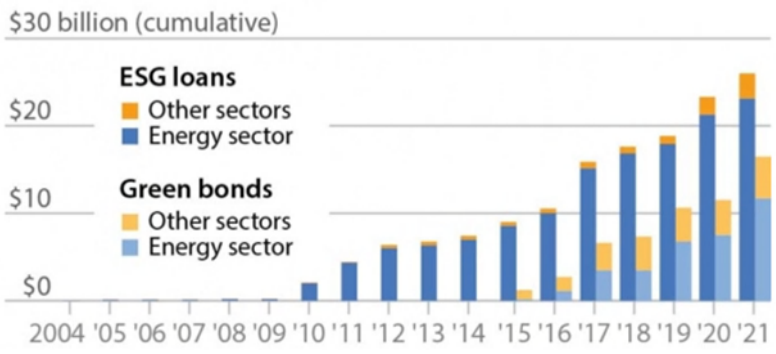
**Figure 22-8: Procedure for Availing Carbon Credits**

## 22.5 Environmental Social Governance (ESG) Investment

### 22.5.1 Trends and Applicability in India

#### (1) Trends in India

According to the research firm Bloomberg NEF, global ESG investments exceeded 1.6 trillion USD in 2021, more than double the amount in 2020. In India, ESG loans, mainly in renewable energy projects, are approximately25 billion USD, and green bonds outstanding are approximately 15 billion USD.




Source: BloombergNEF

**Figure 22-9: Outstanding ESG Investments in India**

More than 70% of green bonds target renewable energy projects. With the issuance of a 500 million USD green bond by Indian Railway Finance Corporation Limited (IRFC), a subsidiary of the Ministry of Railways, in December 2017, further ESG investments are expected in the transportation sector. IRFC has developed a Green Bond Framework compliant with the Climate Bond Standards (CBS) set forth by the Climate Bond Initiative (CBI). IRFC issued another US$500 million green bond in January 2022, and raised US$1.1 billion yen-denominated green loan in March 2022. The outstanding borrowing mix as of March 31, 2022 showed that bonds accounted for 44%, including 121 domestic secured bonds, 48 54EC bonds[63], 13 domestic unsecured bonds, and 6 overseas unsecured bonds.

**Table 22-7: Outline of IRFC Green Bond and Green Loan**

| Category | Green Bond | Green Bond | Green Loan |
|---|---|---|---|
| Name | Reg-S Bonds Green Bond 1st Series (USD 5 Million) | REG-S/144A GREEN BONDS USD 500M | SYND GREEN FCL JPY EQ. USD 700M/400M |
| Year of procurement | December 2017 | January 2022 | March 2022 |
| Amount raised | US$ 500 million | US$ 500 million | US$ 700 million (tranche 1)<br>US$400 million (tranche 2) |
| Period | 10 years | 10 years | 10 years (Tranche 1)<br>7 years (Tranche 2) |
| Interest rate | 3.835% (3.835%) | 3.57% (3.57%) | 6M TONA + 0.93% pa (tranche 1)[64]<br>6M TONA + 0.81% pa (tranche 2) |

[63] Corporate bonds in which capital gains are exempt from taxation. Only three companies, REC (Rural Electrification Corporation Ltd), PFC (Power Finance Corporation Ltd), and IRFC, can issue these bonds in India.
[64] Tokyo Overnight Average Rate

| Category | Green Bond | Green Bond | Green Loan |
|---|---|---|---|
| **Name** | **Reg-S Bonds Green Bond 1st Series (USD 5 Million)** | **REG-S/144A GREEN BONDS USD 500M** | **SYND GREEN FCL JPY EQ. USD 700M/400M** |
| Sources | Bonds issued on the London Stock Exchange, targeting foreign institutional investors.[65] | Bonds issued at GIFT City, India's offshore market, to foreign institutional investors. | Co-financing by Mizuho Bank, MUFG, and SMBC |
| Usage | Based on the "Green Financing Framework" developed by IRFC, the procured funds are used for the following purposes:<br>1. Freight dedicated railway line[66]<br>• All infrastructure, infrastructure upgrades, and freight rolling stock (locomotives, coaches, wagons, trucks, flats, EMUs, containers, cranes, trolleys, and other rolling stock components) for electrified freight lines<br>• All infrastructure, infrastructure upgrades, and freight rolling stock for non-electrified projects that meet freight transport thresholds (25 $gCO_2$ per ton-km)<br>2. Public passenger railway transport<br>• All infrastructure, infrastructure upgrades, and rolling stock of electrified railways<br>• All infrastructure, infrastructure upgrades, and rolling stock of non-electrified projects that meet the passenger transport threshold (50 $gCO_2$ per passenger-km)<br>3. Railroad Business<br>• Rail electrification and all activities related to rail electrification | | |
| Information disclosure | In accordance with the requirements of the Green Bond Standard (GBS), an updated report is required to be submitted that includes the followings:<br>• Amounts raised within the framework of green finance<br>• Certificate confirming end use<br>• Amounts used for defined purposes<br>• List of assets since the end of the fiscal year in which the funds were invested<br>The 2017 report states that 385 electric locomotives were purchased using funds raised through green bonds. | | |

Source: IRFC Annual Report

### (2) Applicability for Metro Projects in India

The Government of India proposes to issue sovereign green bonds for the first time this year. The bonds will mobilize resources for green infrastructure deployed in public sector projects to reduce the economy's carbon intensity.

In the future, it can be proposed that a financial corporation specializing in urban transportation be established under the MoHUA, and a part of the funds raised through green bonds issued by this corporation be used for maintenance and upgrading for the next phases of Patna Metro. Through the interview with DMRC, though they are interested in the green bond, it will be the decision of MoHUA since DMRC follows the guidelines of MoHUA. DMRC is aware that the financial institution under the Ministry of Railway raised the green bonds, which attracted a lot of institutional investors.

## 22.5.2 Information Disclosure on ESG Investments

Security and Exchange Board of India (SEBI) announced that the top 1,000 listed companies (based on market capitalization) are required to submit the Business Responsibility and Sustainability Report (BRSR)

[65] Investors from Asia (Singapore, HK, Taiwan, Tokyo), Europe (Denmark, UK, Germany, Switzerland), and the Middle East. By Investor Type Breakdown was 64% to Fund / Asset Managers, 24% to Insurance, 10% to Banks and Private Banks and 2% to Others https://www.climatebonds.net/resources/press-releases/2017/12/indian-railways-irfc-launches-inaugural-500m-green-bond

[66] Infrastructure and rolling stock on freight-only rail lines built for the primary purpose of transporting fossil fuels are excluded.

relevant to project accountability and sustainability. The sample items disclosed on ESG investments are shown below.

**Table 22-8: Sample Items of Information Disclosure on ESG Investment**

| Categories | Items |
|---|---|
| General | ESG risks and opportunities, risk reduction, financial impact assessment |
| Environment | • Resource consumption amount<br>• GHG emission amount<br>• Waste management<br>• Low energy certificate (PAT scheme) |
| Social | • Workers' and laborers' condition<br>• Community consideration<br>• Consumer measures |
| Governance | • Roles of the board of directors<br>• Action principals |

Source: SEBI

As there is a growing international demand for non-listed companies to disclose information on decarbonization to promote corporate decarbonization activities, it is possible to suggest that the DMRC and PMRCL proactively address the above information disclosure since the activities related to the information disclosure by DMRC are not found as of now.

To the suggestion by JST, DMRC and PMRCL replied that they follow the guidelines as they do in CDM, and MoHUA responded that they are not considering ESG in general at this moment.

# 23. Implementation Plan

## 23.1 Tender Packages (N/A)

## 23.2 Procurement Plan for Materials, Machines, and Equipment (N/A)

## 23.3 Project Implementation Schedule (N/A)

## 23.4 Responsibility of Project Executing Agency

### 23.4.1 Construction Safety Management

#### (1) Comparison between JSSS and CCSHE

For construction safety management, non-JICA packages refer to DMRC's safety manual, while PMRCL agreed to use JICA Standard Safety Specification (JSSS) for the project. The two documents have different compositions as the table below. One significant difference is that DMRC's safety manual is officially named Conditions of Contract on Safety & Health and Environment (hereinafter called CCSHE) and contains the environmental manual.

**Table 23-1: Comparisons between JSSS and DMRC's Safety Manual**

| JSSS | CCSHE (Delhi Metro) |
|---|---|
| **Chapter 1. General Requirements**<br>1.1 Safety Declaration<br>1.2 General Reference Notes<br>1.3 Incorporation of JSSS into the Contract<br>1.4 Compliance with JSSS and Other Regulations<br>1.5 Contractor's Safety Management System<br>1.6 Checking and Validation of Submissions<br>1.7 Contractor's Safety Plan<br>1.8 Risk Assessment<br>1.9 Contractor's Method Statement<br>1.10 Engineer's Safety Representative<br>1.11 Safety Compliance Instructions from the Engineer<br>1.12 Health and Safety Officer at the Site (HSO)<br>1.13 HSO – Scope of Duties and Authority<br>1.14 Procedure for Resuming the Works<br>1.15 Contractor's Safety Management Activities<br>1.16 Joint Site Safety Inspections<br>1.17 Compliance Monitoring and Auditing<br>1.18 Proper Placement of Contractor's Personnel<br>1.19 Safety Training Generally<br>1.20 Safety Induction Training<br>1.21 Skill Training<br>1.22 Dangerous Work<br>1.23 Permit to Work System -Dangerous Work<br>1.24 Accident Response Plan<br>1.25 Measures at the Time Accidents Occur<br>1.26 Emergency Response Plan | **Part – I: Safety & Health and Environment Management**<br>1.0 General<br>2.0 Safety & Health and Environment (SHE) Targets and Goals<br>3.0 Compliance<br>4.0 Contractor Safety & Health and Environment Policies and Plans<br>5.0 Designer's Role<br>6.0 Contractor Safety & Health and Environment Organisation<br>7.0 Contractor Safety & Health and Environment Committee<br>8.0 Safety & Health and Environment Orientation Training<br>9.0 ID Card and First Day at Work<br>10.0 Safety & Health and Environment Training<br>11.0 Site Inspection<br>12.0 Safety & Health and Environment Audit<br>13.0 Safety & Health and Environment Communication<br>14.0 Safety & Health and Environment Submittals to the Employer<br>15.0 Accident Reporting<br>16.0 Accident Investigation<br>17.0 Emergency Preparedness Plan<br>18.0 Expert/Agencies for Safety & Health and Environment Services<br>19.0 Role of Main/Civil Contractor<br>20.0 Installation of CCTV's Cameras |

| JSSS | CCSHE (Delhi Metro) |
|---|---|
| 1.27 Contractor's Safety Committee and Regular Safety Meetings<br>1.28 Engineer's Regular Safety Meetings<br>1.29 Project Safety Committee<br>1.30 Health and Safety Coordination with Other Contractors<br>1.31 Safety Statistics<br>1.32 Health and Safety Records<br>1.33 Safety Reports<br>1.34 Health and Safety Incentive Scheme<br>1.35 Contractor's Equipment, Temporary Works, Safety Equipment and PPE<br>1.36 Health Matters<br>1.37 Design and Management of Temporary Works<br>1.38 Unexploded Ordnance (UXO) | |
| **Chapter 2. General Safety Measures**<br>2.1 Work Environment<br>2.2 Risk Control around the Site<br>2.3 Prohibition of Entry<br>2.4 Spotters<br>2.5 Fall Prevention<br>2.6 Falling Objects<br>2.7 Adverse Weather Requirements<br>2.8 Fire Prevention<br>2.9 PPE and First Aid | **Part – II: Safety**<br>21.0 Housekeeping<br>22.0 Working at Height<br>23.0 Overhead Protection<br>24.0 Slipping, Tripping, Cutting, Drowning and Falling Hazards<br>25.0 Lifting Appliances and Gear<br>26.0 Launching Operation<br>27.0 Construction Machinery<br>28.0 Machine and General Area Guarding<br>29.0 Manual Lifting and Carrying of Excessive Weight<br>30.0 Site Electricity<br>31.0 Lighting<br>32.0 Hand Tools and Power Tools<br>33.0 Welding, Gouging and Cutting<br>34.0 Dangerous and Harmful Environment<br>35.0 Fire Prevention, Protection and Fighting system<br>36.0 Corrosive Substances<br>37.0 Demolition<br>38.0 Excavation and Tunnelling<br>39.0 Work Permit System<br>40.0 Traffic Management<br>41.0 Work to Adjacent Railways<br>42.0 Batching Plant/Casting Yard<br>43.0 Personal Protection Equipments (PPEs)<br>44.0 Visitors to Site<br>45.0 General Issues including Interfaces |
| **Chapter 3. Existing Underground, Concealed and Overhead Services**<br>3.1 Underground and Concealed Services<br>3.2 Overhead Services | **Part – III: Occupational Health and Welfare**<br>46.0 Physical Fitness of Workmen<br>47.0 Medical Facilities<br>48.0 Noise<br>49.0 Ventilation and Illumination<br>50.0 Radiation<br>51.0 Welfare Measures for Workers |
| **Chapter 4. Contractor's Equipment**<br>4.1 General Requirements<br>4.2 Inspection, Maintenance and Repair<br>4.3 Safety Requirements<br>4.4 Ropes, Slings and Chains<br>4.5 Alternative Use of Contractor's Equipment | **Part – IV: Environmental Management**<br>52.0 General Environmental Requirements |

| JSSS | CCSHE (Delhi Metro) |
|---|---|
| 4.6 Hired/Leased Contractor's Equipment<br>4.7 Temporary Fueling Facilities | |
| **Chapter 5. Hoisting and Rigging**<br>5.1 General Requirements<br>5.2 Hoisting Operations<br>5.3 Hoisting Equipment - Cranes<br>5.4 Rigging Equipment | **Part – V: Penalty and Awards**<br>53.0 Changes to Be Recovered from Contractor for Unsafe Act or Condition<br>54.0 Stoppage of Work<br>55.0 Awards<br>56.0 Environmental Penalties<br>57.0 Environmental Awards |
| **Chapter 6. Temporary Works**<br>6.1 General Requirements<br>6.2 Earthwork Support<br>6.3 Cofferdams<br>6.4 Walkways<br>6.5 Scaffolding<br>6.6 Elevated Access Structures<br>6.7 Temporary Electrical Installations<br>6.8 Electric and Gas Welding and Cutting | **Part – VI: Appendix and Sample Forms** |
| **Chapter 7. Excavation Works**<br>7.1 General Requirements<br>7.2 Particular Safety Measures<br>7.3 Manual Excavation Works<br>7.4 Mechanical Excavation Works<br>7.5 Trenches, Pits and Other Types of Structural Excavation<br>7.6 Blasting Works | |
| **Chapter 8. Foundation Piling Works**<br>8.1 General Requirements<br>8.2 Particular Safety Measures | |
| **Chapter 9. Concrete Works**<br>9.1 General Requirements<br>9.2 Particular Safety Measures<br>9.3 Reinforcement<br>9.4 Formwork (Including Falseworks) | |

Source: JST

The following table shows the correspondence between JSSS and CCSHE. As to the significant difference in terms of safety & health management scheme, JSSS involves the Employer and the Engineer as stakeholders in the management, under whose base each clause is specified. JSSS defines the authority of the Health and Safety Officer (HSO) nominated by the Contractor and has the HSO and its team act spontaneously to improve the safety & health management level at the Site. In contrast, CCHSE acknowledges that safety & health management should be the Contractor's responsibility and specifies the requirements on audit and committee (its frequency is more than JSSS, as shown in Table 23-2) and penalty against deviation from CCSHE. This managerial difference can be derived from cultural differences.

It is not easy to judge which type of safety & health management scheme is more effective, considering workers' ability & quality and diverse social backgrounds across workers in the Indian construction industry. If two documents are just combined as they are, various challenges would arise. For instance, if imposing a penalty specified in CCSHE on the HSO, who owns board responsibilities, the HSO might not perform as JSSS expects. Moreover, the Contractor would face difficulty conducting safety & health management,

including audit and committee, for the scope as per JSSS and with the frequency per CCSHE. Selecting higher and more severe provisions between two documents can create an adverse effect on the functional safety & health management quality. Due to these concerns, it is better to analyze the fatal accident cases from JICA funding projects in India and understand locally unique causes to be highlighted.

## Table 23-2: Correspondence between JSSS and CCSHE

| JSSS | CCSHE (Delhi Metro) |
|---|---|
| **Chapter 1. General Requirements** | |
| 1.1 Safety Declaration | 2.0 Safety & Health and Environment (SHE) Targets and Goals<br>3.1 Memorandum of Understanding |
| 1.2 General Reference Notes | 1.0 General |
| 1.3 Incorporation of JSSS into the Contract | |
| 1.4 Compliance with JSSS and Other Regulations | 3.0 Compliance |
| 1.5 Contractor's Safety Management System | 4.0 Contractor Safety & Health and Environment Policies and Plans |
| 1.6 Checking and Validation of Submissions | |
| 1.7 Contractor's Safety Plan | 4.0 Contractor Safety & Health and Environment Policies and Plans |
| 1.8 Risk Assessment | 4.0 Contractor Safety & Health and Environment Policies and Plans<br>5.3 Hierarchy of Risk Control |
| 1.9 Contractor's Method Statement | 5.6 Contractor's Method Statement |
| 1.10 Engineer's Safety Representative | |
| 1.11 Safety Compliance Instructions from the Engineer | |
| 1.12 Health and Safety Officer at the Site (HSO) | 6.0 Contractor Safety & Health and Environment Organisation |
| 1.13 HSO – Scope of Duties and Authority | 6.0 Contractor Safety & Health and Environment Organisation |
| 1.14 Procedure for Resuming the Works | 54.0 Stoppage of Work |
| 1.15 Contractor's Safety Management Activities | 7.0 Contractor Safety & Health and Environment Committee<br>11.0 Site Inspection |
| 1.16 Joint Site Safety Inspections | 11.0 Site Inspection |
| 1.17 Compliance Monitoring and Auditing | 12.0 Safety & Health and Environment Audit |
| 1.18 Proper Placement of Contractor's Personnel | 9.0 ID Card and First Day at Work<br>10.0 Safety & Health and Environment Training |
| 1.19 Safety Training Generally | 10.0 Safety & Health and Environment Training |
| 1.20 Safety Induction Training | 8.0 Safety & Health and Environment Orientation Training |
| 1.21 Skill Training | 10.0 Safety & Health and Environment Training |
| 1.22 Dangerous Work | 39.0 Work Permit System |
| 1.23 Permit to Work System -Dangerous Work | 39.0 Work Permit System |
| 1.24 Accident Response Plan | 15.0 Accident Reporting<br>47.0 Medical Facilities |
| 1.25 Measures at the Time Accidents Occur | 15.0 Accident Reporting<br>16.0 Accident Investigation |
| 1.26 Emergency Response Plan | 17.0 Emergency Preparedness Plan |
| 1.27 Contractor's Safety Committee and Regular Safety Meetings | 7.0 Contractor Safety & Health and Environment Committee |
| 1.28 Engineer's Regular Safety Meetings | |
| 1.29 Project Safety Committee | |
| 1.30 Health and Safety Coordination with Other Contractors | 7.6 Co-contractor's Participation<br>19.0 Role of Main/Civil Contractor |

| JSSS | CCSHE (Delhi Metro) |
|---|---|
| 1.31 Safety Statistics | 14.0 Safety & Health and Environment Submittals to the Employer |
| 1.32 Health and Safety Records | 14.0 Safety & Health and Environment Submittals to the Employer |
| 1.33 Safety Reports | 14.0 Safety & Health and Environment Submittals to the Employer |
| 1.34 Health and Safety Incentive Scheme | 13.0 Safety & Health and Environment Communication<br>55.0 Awards |
| 1.35 Contractor's Equipment, Temporary Works, Safety Equipment and PPE | Various provisions in Part-II Safety |
| 1.36 Health Matters | 47.0 Medical Facilities<br>51.0 Welfare Measures for Workers |
| 1.37 Design and Management of Temporary Works | 5.0 Designer's Role |
| 1.38 Unexploded Ordnance (UXO) | |
| | |
| | 18.0 Expert/Agencies for Safety & Health and Environment Services |
| | 20.0 Installation of CCTV's Cameras |
| | |
| **Chapter 2. General Safety Measures** | |
| 2.1 Work Environment | 21.0 Housekeeping<br>31.0 Lighting<br>34.0 Dangerous and Harmful Environment<br>48.0 Noise<br>49.0 Ventilation and Illumination<br>50.0 Radiation |
| 2.2 Risk Control around the Site | 40.0 Traffic Management |
| 2.3 Prohibition of Entry | 44.0 Visitors to Site<br>46.0 Physical Fitness of Workmen |
| 2.4 Spotters | |
| 2.5 Fall Prevention | 22.0 Working at Height |
| 2.6 Falling Objects | 22.0 Working at Height<br>23.0 Overhead Protection<br>24.0 Slipping, Tripping, Cutting, Drowning and Falling Hazards |
| 2.7 Adverse Weather Requirements | 17.0 Emergency Preparedness Plan |
| 2.8 Fire Prevention | 35.0 Fire Prevention, Protection and Fighting system |
| 2.9 PPE and First Aid | 36.0 Corrosive Substances<br>43.0 Personal Protection Equipments (PPEs)<br>47.0 Medical Facilities |
| **Chapter 3. Existing Underground, Concealed and Overhead Services** | |
| 3.1 Underground and Concealed Services | |
| 3.2 Overhead Services | |
| **Chapter 4. Contractor's Equipment** | |
| 4.1 General Requirements | |
| 4.2 Inspection, Maintenance and Repair | 27.0 Construction Machinery<br>32.0 Hand Tools and Power Tools |
| 4.3 Safety Requirements | 27.0 Construction Machinery<br>32.0 Hand Tools and Power Tools |

| JSSS | CCSHE (Delhi Metro) |
|---|---|
| 4.4 Ropes, Slings and Chains | 25.0 Lifting Appliances and Gear |
| 4.5 Alternative Use of Contractor's Equipment | 27.0 Construction Machinery |
| 4.6 Hired/Leased Contractor's Equipment | 27.0 Construction Machinery |
| 4.7 Temporary Fueling Facilities | |
| **Chapter 5. Hoisting and Rigging** | |
| 5.1 General Requirements | |
| 5.2 Hoisting Operations | 25.0 Lifting Appliances and Gear |
| 5.3 Hoisting Equipment - Cranes | 25.0 Lifting Appliances and Gear |
| 5.4 Rigging Equipment | 25.0 Lifting Appliances and Gear |
| **Chapter 6. Temporary Works** | |
| 6.1 General Requirements | |
| 6.2 Earthwork Support | 38.0 Excavation and Tunnelling |
| 6.3 Cofferdams | |
| 6.4 Walkways | 22.0 Working at Height |
| 6.5 Scaffolding | 22.0 Working at Height |
| 6.6 Elevated Access Structures | 22.0 Working at Height |
| 6.7 Temporary Electrical Installations | 30.0 Site Electricity |
| 6.8 Electric and Gas Welding and Cutting | 33.0 Welding, Gouging and Cutting |
| **Chapter 7. Excavation Works** | |
| 7.1 General Requirements | |
| 7.2 Particular Safety Measures | 38.0 Excavation and Tunnelling |
| 7.3 Manual Excavation Works | 38.0 Excavation and Tunnelling |
| 7.4 Mechanical Excavation Works | 38.0 Excavation and Tunnelling |
| 7.5 Trenches, Pits and Other Types of Structural Excavation | 38.0 Excavation and Tunnelling |
| 7.6 Blasting Works | |
| **Chapter 8. Foundation Piling Works** | |
| 8.1 General Requirements | |
| 8.2 Particular Safety Measures | |
| **Chapter 9. Concrete Works** | |
| 9.1 General Requirements | |
| 9.2 Particular Safety Measures | |
| 9.3 Reinforcement | |
| 9.4 Formwork (Including Falseworks) | |
| | |
| | 26.0 Launching Operation |
| | 28.0 Machine and General Area Guarding |
| | 29.0 Manual Lifting and Carrying of Excessive Weight |
| | 37.0 Demolition |
| | 39.0 Work Permit System |
| | 41.0 Work to Adjacent Railways |
| | 42.0 Batching Plant/Casting Yard |
| | 45.0 General Issues including Interfaces |
| | 51.0 Welfare Measures for Workers |

Source: JST

**Table 23-3: Difference of Safety Management System**

| JSSS | CCSHE (Delhi Metro) |
|---|---|
| **Inspection**<br>- **HSO's Daily Site Safety Inspection (1.13)**<br>- **Weekly Joint Site Inspection with the Engineer led by HSO (1.16)** | **Inspection**<br>- Daily Routine Inspection (11.1.5)<br>- Planned General Inspection with the Employer (11.1.4)<br>- Specific Inspection (11.1.6) |
| **Committee Meeting**<br>- **Monthly Safety Committee Meeting by the Contractor (1.27)**<br>- **Monthly Engineer's Safety Committee Meeting (1.28)**<br>- **Periodical Project Safety Committee by the Employer (1.29)** | **Committee Meeting**<br>- Weekly Site SHE Committee Meeting by the Contractor (7.5)<br>- Monthly SHE Committee meeting by the Contractor with attendance of the Employer (7.4) |
| **Emergency Training**<br>- **Semi-annual Emergency Response Training (1.26)** | **Emergency Training**<br>- Monthly Emergency Mock Drill (17.5) |
| **Audit**<br>- **Annual Audit by the Contractor's Head Office (1.17)** | **Audit**<br>- Monthly Safety & Health Audit with Scoring by the Contractor and Employer (12.1.2)<br>- Monthly Electrical Safety and Labour Audit with the Employer (12.1.3)<br>- Quarterly External Safety & Health Audit (12.1.4) |

Source: JST

## (2) Fatal Accident Analysis

JST reviewed the summary of the fatal accident cases in JICA's project in India, consisting of 27 accidents. It would be statistically inappropriate to underestimate some safety measures through the analysis due to sample scarcity. However, it is meaningful to understand the difference from cases in Japan to improve local safety & health management standard. JST extracted three significant types of the 27 fatal accidents as below.

**Table 23-4: Significant Types of Fatal Accident Cases**

| Type | Applicable Cases | Total number |
|---|---|---|
| **Third-party** | 1, 4, 6, 12, 21, 25 | 6 |
| **Heavy Machinery** | 1, 3, 4, 6, 10, 14, 16, 17, 18, 19, 23, 25, 26 | 13 |
| **Crane & Slinging** | 7, 9, 15, 22, 26 | 5 |

Source: JST

### 1) Third-party Accident

Third-party accidents involving people outside the construction activity should be avoided the most. As JSSS Sub-clause 2.2 mentioned, setting a proper boundary around the Site and ensuring smooth local traffic are crucial against third-party accidents. Besides, communicating via local languages with the local community also takes an essential role in the soft aspect, as stressed in JSSS Sub-clause 2.2.6. By the way, there are four cases where outsiders entered the Site. Out of the four, three accident cases (#1, #4, and #6) were caused by heavy machines or vehicles running over the victim. Additionally, the case (#25), which happened out of the Site, was likely caused by the poor maintenance of a construction truck. These causes can be minimized by safety measures toward construction machines and vehicles mentioned in the following sub-section.

### 2) Heavy Machinery and Vehicle Accident

#### (i) Spotter

Out of the 27, heavy machines and vehicles are the highest cause, which counts 13. It is not seemingly because victims who were in the blind spot of operators were squeezed into rotating parts. Instead, they seemed to be run over by a linearly moving machine. Spotters are generally aligned at the Site in Japan to prevent a heavy machinery or vehicle accident. JSSS Sub-clause 2.4 also refers to the importance of spotters. If the Contractor aligns the spotter and educates operators to follow the spotter's instruction, eight fatal cases (#1, #4, #6, #10, #14, #16, #18, and #23) could be eliminated. On the other hand, in two cases (# 16 and #23), workers who acted like the spotter were run over.

Regardless of within the Site, the typical feature of local citizens toward safety awareness in daily life is "cutting in a line." This applies not only between persons but also between vehicles and a person versus a car. Prioritization for the weak in the traffic is not considered, which causes many near misses in a daily traffic. There is a driver with a lack of consideration or a selfish prejudice that the opponent probably stops to escape it. Properly aligning the spotter with the authorization to direct heavy machines' and vehicles' movement should be an effective measure.

#### (ii) Mobile Crane Movement with Suspended Load

Moving a mobile crane with a suspended load is prohibited, in principle, in Japan, as per the government's notice. However, under some inevitable conditions, the mobile crane with crawlers is allowed to move by suspending objects under a specific restriction per Japan Crain Association Specification.

On the other hand, contractors commonly use a pick-and-carry hydra crane (wheel-type mobile crane) with a suspended load in India. The summary of required machinery prepared by PMRCL attached to the tender documents also shows multiple numbers (not known if they are prohibited from moving by suspending objects). Two fatal cases (#18 and #23) were reported due to moving a mobile crane with a suspended load. It appears JSSS Sub-clause 5.3.2 (10) is specified as the basis of the prohibition of mobile crane movement with a suspended load. It is necessary to check relevant clauses of local rules and regulations and standard practices in major projects to decide the degree of integration of two safety & health specifications to prevent accidents related to mobile cranes.

#### (iii) Inspection of Construction Vehicles

Two fatal accidents (#19 and #25) are reported due to the breaking failure of construction vehicles.

The Contractor should comply with JSSS Chapter 4 to check and maintain its machinery to be in good condition. Compared with machinery and equipment within the Site, monitoring heavy vehicles coming and going from/to the Site may be more challenging. However, the Contractor should register the list of mobilized trucks by checking the maintenance certificate in advance and manage them as practically as possible.

#### 3) Crane and Slinging Works

Five fatal accidents related to crane works (#3, #17, #18, #23, and #26) and slinging works (#7, #9, #15, #22, and #26) are reported, respectively. The accidents within a team of each crane or slinging work were likely caused due to poor consensus about the task sequence among members. The Contractor should have all workers engaged in the specific work to keep a common understanding of the work method in mind per JSSS Sub-clause 1.9 Method Statement. Besides, crane or slinging works should be executed by a skillful and qualified person with thorough training, as JSSS Sub-clause 5.3.1 and 5.2.2 (2) described. It will be necessary to check the implementation of the local licensing system to reflect it for the integration between JSSS and CCSHE.

Additionally, three fatal accidents (#7, #9, and #22) happened involving workers who worked for other activities due to blunders during crane or slinging works. Contractors in Japan exhibit a slogan, "Do not come under suspended objects," at the Site. They generally create a dedicated area for crane works by aligning a spotter and keeping out workers irrelevant to the crane work. Coordination across activities in dense areas should be the main contractor's core responsibility. Especially in underground metro projects where various contractors should share limited openings for lowering materials and equipment, such coordination is very crucial. The Contractor should manage it as per JSSS Sub-clause 1.30.

#### 4) Method Statements and Education

The fundamental source for construction safety management in Japan is to prepare method statements and modify bugs, if any. When an incident occurs, the contractors would be directly punished if the method statement is not maintained. The method statement should include not only methodology and sequence of specific works but also the note about checking the circumstances immediately before starting works (several sub-clauses in JSSS), guidance by the spotter (JSSS Sub-clause 2.4), a particular action taken during severe weather or emergency (JSSS Sub-clause 4.3.13) and others. The Contractor should educate all workers involving the specific tasks with the relevant method statement (JSSS Sub-clause 1.9).

It is observed that there is no fatal accident case related to falling or collapse of temporary concrete supporting in the 27 accident cases. CCSHE indicates the standard diagram and a checklist of temporary scaffolds and pathways. Besides, DMRC's typical Employer's Requirement puts the condition where the proof strength of materials for temporary structures should be the same value as for permanent structures for stress calculations. As a result, it is envisaged that temporary structures hold a buffer enough against an unexpected load. Other Japanese ODA projects in India may implement safety management similar to DMRC's one. However, as mentioned at the beginning of this section, with the minimal number of cases, it is not reasonable to conclude that the safety risk of some works is negligible. This review result should remain a reference, and JSSS's contents, including tasks and activities not listed in the 27 fatal accident cases, should be taken care of.

### (3) Integration Plan between JSSS and CCSHE

#### 1) Weighted Considerations

The following safety aspects should be incorporated into the integration based on the review described in the preceding section when JSSS and CCSHE are integrated. It will be better to prepare practical and

user-friendly integrated documents with a local expert's input to survey local regulations and practices, if necessary. Regarding accidents distinguished in metro projects like a collapse of rock strata during tunneling and destabilization of excavating ground at the shaft due to high water head, suitable engineering measures at the planning stage should minimize the accidental risk. As JSSS does not include specific technical provisions for these works, the integrated document does not refer to them elaborately. Instead, a review of technical requirements/specifications for the Contract will take an essential role against such construction accidents.

- Stressing the importance against third-party accidents
- Implementation of aligning a spotter
- Inspection of heavy machines and construction vehicles
- Checking requirements about restriction over mobile cranes
- Practical management of licensing systems (especially for crane and slinging works)
- Coordination across working groups and with other contractors during crane works
- Practical management and improvement of method statements

#### 2) Integration Method

For integrating two documents, the Particular Safety & Health Specification (PSHS) will be created as the more prioritized than JSSS and CCSHE. This is because literary integration into one document will not be reasonable while keeping each advantage of documents that are backed by different safety cultures. PSHS will be a supplement of CCSHE and prepared by following the content sequence of CCSHE, which complies with local rules and is familiar to local stakeholders.

PSHS will be prepared by inserting a reference to specific JSSS Sub-clauses or adding concepts of JSSS to CCSHE, most of which are in red in Table 23-2. The list may increase during the integration activity, but the following items are planned to be referred to or added.

(i) Referring to JSSS Sub-Clause: PSHS refers to the following JSSS Sub-clause.

Engineer's engagement (1.10, 1.11, 1.28, and 1.29), Spotter (2.4), Utility diversion/ suspension (3), Earthwork support (6.2), Cofferdam (6.3), Blasting (7.6), Foundation works (8), Concrete works (9)

(ii) Adding JSSS's concept: While all contents of CCSHE are reviewed, it will be added to PSHS if JSSS's vision or Japanese safety management knowledge applicable to projects in India is missing. The following items are identified as stress. Measures against third-party accidents (2.2), Machinery inspections (4), Licensing system (5.3.1 and 5.22), Coordination with other contractors (1.30), Method statement and education (1.9), Measures during bad weather (4.3.13).

### (4) PMRCL's Safety Management Team

Following JSSS requests PMRCL to allocate more resources to safety management than other projects. Attachment 25 describes the digest about difference of the construction safety management.

While establishing its organization, PMRCL has not employed the general manager (safety) and other staff in charge of construction safety management. PMRCL will hire an independent consultant consisting of 18

to 20 local experts to monitor DMRC's performance as the implementing agency. The scope of the independent consultant includes construction safety management, which helps PMRCL meet an acute project management demand while many construction activities are happening.




Signboard



Works and Storage Area

Source: JST

**Figure 23-1: Construction Depot Status for PC-04**

### 23.4.2 Land Acquisition

Chapter 15 Social Impact Assessment mentions the legal framework for the land acquisition process. Whereas the physical arrangement relating to construction works is described in this section.

#### (1) Construction Depot

PMRCL prepared the land acquisition drawing, including for construction depots. The construction depot for the underground civil contractor in Corridor-2 is sufficient using space in the college and stadium. The one for Corridor-1 seems less than required. The contractors for PC-05 and 06 will need to initiate an additionally required temporary land use agreement with landowners immediately after the Letter of Acceptance issue.

#### (2) Casting Yard

Information about existing casting yards rendered to PC-01 and PC-04 contractors refers to Sub-chapter 5.4.2 (2) Construction. PMRCL will arrange the yard for PC-05 and 06 though they have not finalized the location yet.

#### (3) Muck Disposal Site

The PC-01 Contractor identified a muck disposal site near New ISBT. The site belongs to a farmer, and the contractor disposes of much for free. The land along the road is 3-4 meters below the road. Hence, the landowner does not claim any fee considering the preparation of the future land development. PMRCL will arrange muck disposal sites for PC-05 and 06 Contractor though they have not finalized the location yet.




Source: JST

**Figure 23-2: Muck Disposal Site for PC-01**

### 23.4.3 Transferring PAP

Please refer to Chapter 15 Social Impact Assessment.

### 23.4.4 Relocating Obstacles

#### (1) Utility Diversion

PMRCL hired contractors apart from the main civil contractors to divert power lines over the road for both corridors. Concerning underground utilities, the civil contractors should divert or suspend during the contract after permission from utility owners. However, it does not seem to take material time to get it (one week or so), according to an interview with PC-01 & 03 Contractor and DMRC. PMRCL prepared underground utility identification drawings for both corridors.

#### (2) Tree Cut / Replantation

PMRCL already got permission to cut trees affected by construction works from Forest Department/ Municipal Authorities. However, contractors may need to cut more trees in line with their construction methodology as the area for the construction depot seems limited, as mentioned in Sub-chapter 5.4.2 (2) Construction.

### 23.4.5 Obtaining Permissions

Permissions PMRCL and the contractors should take from local relevant authorities for construction activities in advance are summarized as followings.

**Table 23-5: Permission Required for Construction**

| Permission Type | Authority | Responsibility |
|---|---|---|
| Working on Roads | Road Construction Department | Contractor |
| Traffic Diversion | Traffic Police | Contractor |
| Utility Diversion | Utility Owners | Contractor |
| Railway Crossing | East Central Railway | PMRCL |

Source: JST

#### (1) Traffic Diversion

The contractors should get no objection from local traffic police for road diversion and temporary road occupation. No objection needs even for preparatory works like geotechnical investigation, and the contractors should focus on the application first. PMRCL will not physically support the contractors as other metro projects in India.

#### (2) Railway Crossing

PMRCL got permission from East Central Railway to underpass at-grade and elevated live railway lines with conditions where clearance from metro tunnels is fixed, and the contractors should monitor the rail level during the construction. The contractors should get approvals for detailed working plans before the construction. The general permission from Indian Railway is good momentum for the project execution, while the approval from Indian Railway usually takes material time.

### 23.4.6 Empowerment for Women and the Needy

Regarding gender consideration, PMRCL should take care of it for (i) station design, (ii) employment during the O&M phase, and (iii) provision of lady's car, which are described in Sub-chapter 15.13.2 Consideration on Gender.

JST acknowledged that Indian Rail offers a discounted tariff for Scheduled Castes, Scheduled Tribes, and Differently Abled Persons. PMRCL may want to refer to the scheme.

## 23.5 Measure against COVID-19

The government of India and the Bihar State government do not impose any restrictions relating to COVID-19 now. Even when the situation is the worst in May 2021, the mortality rate due to COVID-19 (3 persons per million per day) was much lower than in G7 countries except for Japan.

During the pandemic, the central government developed an app called Aarogya Setu and instructed to check travelers' possible infection status at gates where people get together like shopping malls, offices, and stations. In addition, the central government established the online vaccination portal called Co-Win where people easily make an appointment to get vaccinations and maintain the record of vaccines taken in. People, including foreigners, register their individual number (Aadhaar number) in the Co-Win, so the individual data is linked to the specific person, which makes monitoring vaccine status easier.

The Contractors in this project get all workers vaccinated (at least two doses). The cost of one vaccine shot is around 2-300 Rs. (about 400JPY), though the price fluctuates. The cost of vaccination will not be a significant additional burden for the contractors.

## 23.6 Organization during Construction

As Patna city develops, PMRCL creates its organization and expands its functionality. PMRCL agreed with DMRC that DMRC takes total care of the metro implementation, including potential O&M engagement. Accordingly, DMRC, on behalf of PMRCL, is managing the preceding contract packages in Corridor-1 and 2. Unlike a pure government entity, PMRCL is a special purpose vehicle (SPV) that does not always

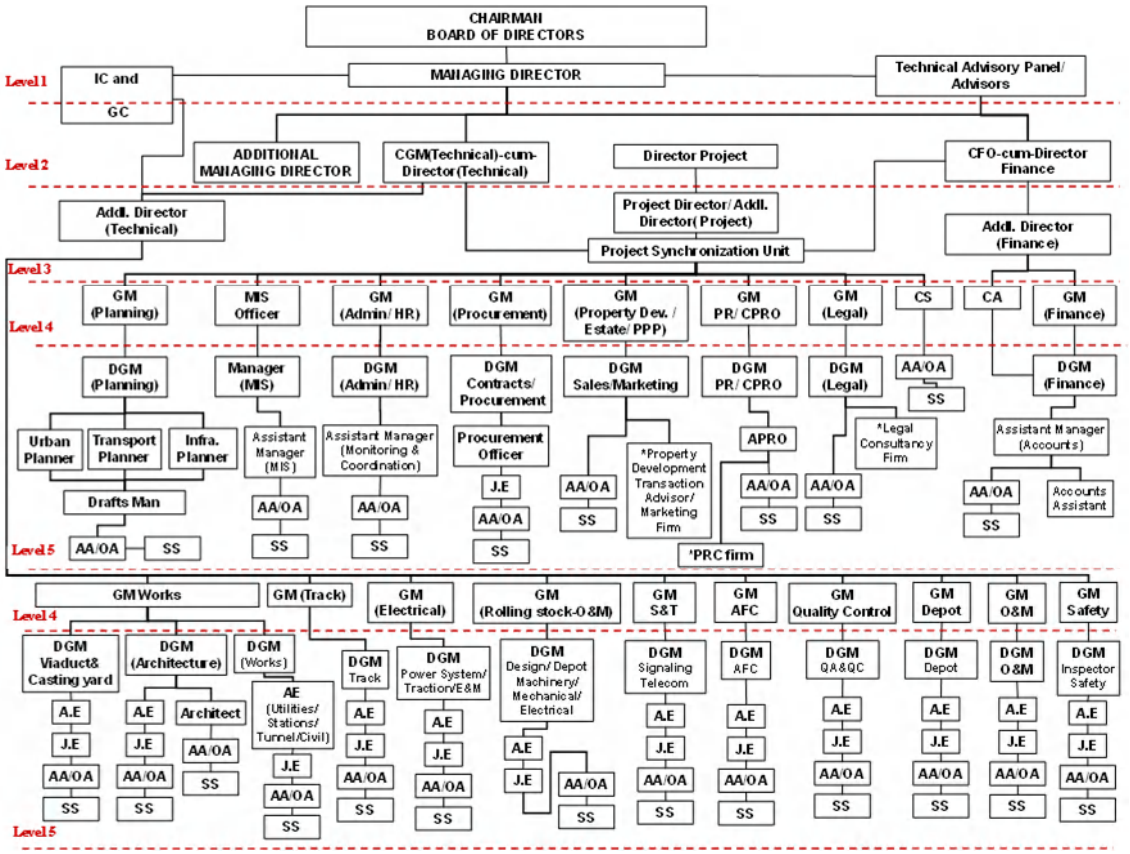
continue its role and responsibility for the future. PMRCL should consider its future operational vision to expand its organization while labor-related issues are challenging all over India. That is, whereas the construction has started and will end in four years, PMRCL should judge if (1) they can quickly establish a capable team catering to the metro project and (2) it is reasonable to dissolve the incubated team in four (plus some) years.

There may be an option where PMRCL concentrates on legal, financial, and administrative tasks they have to deal with as an SPV while subletting technical activities to DMRC and others that PMRCL may employ from the market. PMRCL may not have to duplicate the process DMRC underwent a couple of decades ago. Through this concentration, PMRCL can save effort and cost significantly.

### 23.6.1 PMRCL organization structure

PMRCL was established on February 19, 2019, to implement the Patna Metro Construction Project. It appears that 188 posts in the Patna Metro Company, as shown in the following table and figure, have been approved by the Bihar Urban Development and Housing Authority.

Of these, 30 posts of urgent need will be filled immediately and the remaining posts will be filled from time to time as per the requirement.




Source: PMRCL/DMRC

**Figure 23-3: Organization Structure of PMRCL**

## Table 23-6: PMRCL Organizational Structure Chart

| No. | Name of Post | Number of Post |
|---|---|---|
| 1 | MANAGING DIRECTOR (MD) | 1 |
| 2 | Additional Managing Director(AMD) | 1 |
| 3 | Chief General manager(Technical) cum-Director Technical | 1 |
| 4 | Director Project | 1 |
| 5 | Chief finance officer –cum-Director -finance | 1 |
| 6 | Additional director (Technical) | 1 |
| 7 | Project director –cum-Additional Director (project) | 1 |
| 8 | Project Synchronization Unit (1.Deputy in charge, 2.Project coordinator and Liaisoning Officer, 3.Planner/scheduler-system) | 3 |
| 9 | Addl. Director(Finance) | 1 |
| 10 | GM (Planning) | 1 |
| 11 | MIS Officer | 1 |
| 12 | GM (Administration &HR) | 1 |
| 13 | GM(Legal) | 1 |
| 14 | GM (Property development/Estate/PPP) | 1 |
| 15 | GM PR/CPRO | 1 |
| 16 | GM(Legal) | 1 |
| 17 | CS(Company secretary) | 1 |
| 18 | CA(Chartered Accountant)/CA Firm | 1 |
| 19 | General manage (finance) | 1 |
| 20 | GM Works | 2 |
| 21 | GM Track | 1 |
| 22 | GM Electrical | 1 |
| 23 | GM Rolling Stock-O&M | 1 |
| 24 | GM S&T | 1 |
| 25 | GM Automatic Fare Collection (AFC) | 1 |
| 26 | GM Quality Assurance and Quality Control | 1 |
| 27 | GM Depot | 1 |
| 28 | GM Operation & Maintenance | 1 |
| 29 | GM Safety | 1 |
| 30 | Deputy general manager Planning | 1 |
| 31 | Manager MIS | 1 |
| 32 | Asst. Manager-MIS | 1 |
| 33 | Deputy General Manager(Admin/HR/Project) | 1 |
| 34 | Deputy General manager(Contracts/Procurement/) | 1 |
| 35 | Deputy General manager(Sales & Marketing) | 1 |
| 36 | Deputy General manager PR | 1 |
| 37 | Deputy General manager(Legal) | 1 |
| 38 | Deputy General manager(Finance-Foreign-Indian currency) | 1 |
| 39 | Deputy General manager Viaduct and Casting Yard | 1 |
| 40 | Deputy General manager(Architecture) | 1 |
| 41 | Deputy General manager Works | 3 |
| 42 | Deputy General manager Track | 1 |

| No. | Name of Post | Number of Post |
|---|---|---|
| 43 | Deputy General manager (Power station、Traction、E&M) | 3 |
| 44 | Deputy General manager-Rolling stock (1.Design, 2.Depot Machinery, 3.Mechanical, 4. Electrical) | 4 |
| 45 | Deputy General Manager Signalling And Telecommunication | 1 |
| 46 | Deputy General manager AFC | 1 |
| 47 | Deputy General Manager Quality Assurance and Quality Control | 1 |
| 48 | Deputy General Manager Depot | 1 |
| 49 | Deputy General Manager Operation and Maintenance | 1 |
| 50 | Deputy general manager Safety | 1 |
| 51 | Urban Planner | 2 |
| 52 | Transport planner | 2 |
| 53 | Infrastructure Planner | 1 |
| 54 | Asst. Manager-admin(Monitoring& Coordination) | 2 |
| 55 | Procurement Officer | 1 |
| 56 | APRO | 1 |
| 57 | Asst. Manager Finance | 1 |
| 58 | Architect | 1 |
| 59 | Asst. Engineer (Utilities, Stations, Tunnel, Viaduct) | 4 |
| 60 | Assistant engineer | 19 |
| 61 | Section Engineer/J.E | 20 |
| 62 | Drafts Man | 1 |
| 63 | PPS | 1 |
| 64 | PS/PA | 5 |
| 65 | Stenographer(English/Hindi) | 8 |
| 66 | Accounts Assistant | 1 |
| 67 | Administrative Assistant –Office Assistant (AA-15.OA-14) | 29 |
| 68 | Supporting Staff | 29 |
| | Total | 188 |

Source: PMRCL／DMRC

The following table shows the composition of PMRCL's board of directors, which consists of the Ministry of Housing and Urban Affairs (MoHUA) of the Government of India and relevant departments of the Bihar State Government involved in the decision-making process of PMRCL.

**Table 23-7: List of Board Members/Directors of PMRCL (24.05.2022)**

| S.N | Name | Designation | Nomination |
|---|---|---|---|
| 1 | Shri. Surendrakumar Bagde,<br>Additional Secretary, Ministry of Housing & Urban Affairs, Government of India | Chairman | Nominee Director,GoI |
| 2 | Shri. Anand Kishor,<br>Principal Secretary, Urban Development & Housing Department, Government of Bihar | Managing Director | Nominee Director,GoB |
| 3 | Shri. Jaideep<br>Joint Secretary, Ministry of Housing & Urban Affairs, Government of India | Director | Nominee Director,GoI |
| 4 | Shri. Mahesh Kumar<br>Director (Project), Maharashtra Metro Rail Corporation Ltd | Director | Nominee Director,GoI |
| 5 | Shri Ajit Kumar Jha,<br>ED/CE (G), Railway Board, Ministry of Railways, Government of India | Director | Nominee Director,GoI |
| 6 | Shri. Mahendra Kumar<br>Director (Electrical),National Capital Region Transport Corporation Limited | Director | Nominee Director,GoI |
| 7 | Smt. Shailaza Sharma<br>Addl. Secretary Road Construction Department, Government of Bihar | Director | Nominee Director, GoB |
| 8 | Shri. Satish Kumar<br>Singh Special Secretary, Urban Development & Housing Department, Government of Bihar | Director | Nominee Director, GoB |
| 9 | Shri. Mithilesh Mishra,<br>Additional Secretary, Finance Department, Government of Bihar | Director | Nominee Director, GoB |
| 10 | **Vacant<br>Joint Secretary, Transport Department, Government of Bihar | Director | Nominee Director, GoB |

Source: PMRCL/DMRC

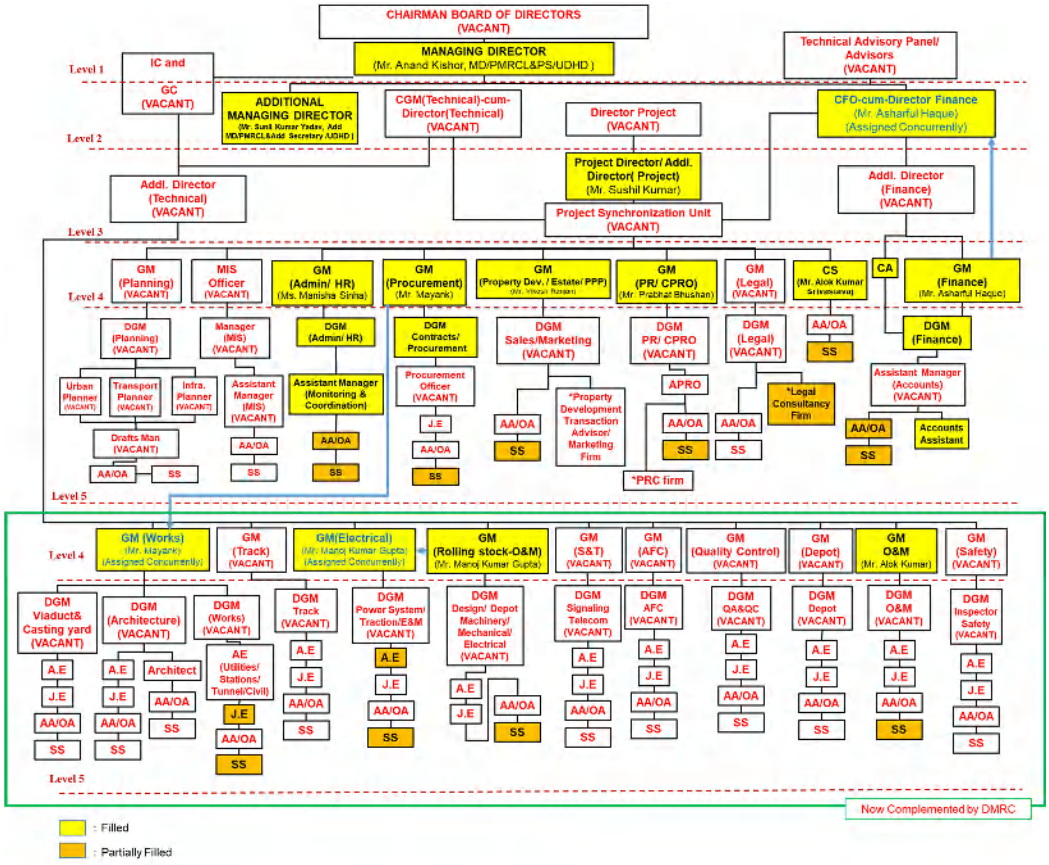
Since PMRCL does not employ any special staff for EIA and SIA currently, some engineers from other sectors also have responsibility for EIA and SIA. Currently, the senior-level staff is seconded to PMRCL from another organization to assist from a professional viewpoint and to participate in coordination between the District Administration, DMRC and JST. In the future, the organisation should be expanded to have a manpower equivalent to DMRC's team of 10-12 environmental and social members, with that staff as leaders and employing younger class staff who can collect and manage data, to prepare for monitoring during the implementation phase and future implementation of the extension project. In discussions between JST and PMRCL/DMRC in this regard, the above-mentioned organisational structure has been confirmed by PMRCL as appropriate for the future vision of PMRCL.

Therefore, JST will propose to PMRCL to actively hire some staff according to the scale and progress of the project. As an example of DMRC, there was a few staff for EIA and SIA when inaugurated, but currently there are dozens of staff in the sector by hiring staff little by little every year.

For the construction and O&M of the Patna Metro, a Memorandum of Understanding (MOU) has been signed between DMRC and PMRCL, which states that the bidding and contracting for procurement of civil works and system services required for the project and the implementation of the works will be carried out by DMRC on behalf of PMRC. It is noted that if PMRCL so desires, DMRC may operate and maintain the project until PMRCL has made adequate O&M arrangements.

In the current PMRCL's organizational chart, the GM positions are mainly filled. During project implementation phase, DMRC functionally complements some of the vacant posts of PMRCL under the MOU. DMRC functionally complements mainly technical sectors of the PMRCL (Figure 23-4). In order

for the PMRC to operate independently and sustainably and to build a structure, it is necessary to plan for the employment of personnel with a view to the duration of the contract with the DMRC.




Source: PMRCL/DMRC

**Figure 23-4: Organisational chart of the operational status of the PMRCL**

The total number of DMRC personnel working on the Patna Metro Construction Project is 174, of which 120 are posted and working in Patna. Personnel working on the project in Delhi also go to Patna to work on a need-to-work basis.

**Table 23-8: Organization Chart for Patna Metro Rail Project, DMRC**

| Department | Position | Number of personnel | Posted at Patna | Posted at Delhi |
|---|---|---|---|---|
| CIVIL | Project Director-1 | 1 | 1 | 0 |
| | Project Director-2 | 1 | 1 | 0 |
| | JGM/Civil | 1 | 1 | 0 |
| | Sr.DGM/Civil | 1 | 1 | 0 |
| | DGM/Civil | 5 | 5 | 0 |
| | Manager/Civil | 4 | 4 | 0 |
| | AM/Civil | 13 | 13 | 0 |
| | SSE/Civil | 1 | 1 | 0 |
| | SE/Civil | 1 | 1 | 0 |
| | ASE/Civil | 18 | 18 | 0 |
| | JE/Civil | 34 | 34 | 0 |
| | Assistant Corporate Communication | 1 | 1 | 0 |
| | Hd. CRA | 1 | 1 | 0 |

| Department | Position | Number of personnel | Posted at Patna | Posted at Delhi |
|---|---|---|---|---|
| Environment | ED/Env | 1 | 0 | 1 |
| | DGM/Env | 1 | 1 | 0 |
| | AM/Env | 1 | 1 | 0 |
| DESIGN/TECHNICAL | CE/Design-II | 1 | 0 | 1 |
| | DGM/Design | 1 | 0 | 1 |
| | Manager/Design-I | 1 | 0 | 1 |
| | Manager/Design-II | 1 | 0 | 1 |
| | AM/Design | 1 | 0 | 1 |
| SIGNAL AND TELECOM & AFC | GM/S&T/Patna | 1 | 0 | 1 |
| | GM/IT | 1 | 0 | 1 |
| | Sr. DGM/S&T | 1 | 0 | 1 |
| | JGM/AFC | 1 | 0 | 1 |
| | Manager/S&T | 2 | 0 | 2 |
| | MGR/AFC | 1 | 0 | 1 |
| | SSE/AFC | 1 | 0 | 1 |
| | SE/IT | 1 | 0 | 1 |
| | SE/A&T | 4 | 0 | 4 |
| | ASE/S&T | 2 | 0 | 2 |
| | JE/S&T | 1 | 0 | 1 |
| ARCHITECT | CA-II | 1 | 0 | 1 |
| | Dy.CA | 2 | 0 | 2 |
| | Manager/Arch. | 2 | 0 | 2 |
| | AM/Arch | 1 | 0 | 1 |
| | Architect Assistant | 4 | 0 | 4 |
| ELECTRICAL | Advisor/E/UD/Patna | 1 | 1 | 0 |
| | GM/E/UG-1 | 1 | 0 | 1 |
| | Dy.CEE | 1 | 1 | 0 |
| | JGM/E/UG-1A | 1 | 0 | 1 |
| | JGM/E/UG-1B | 1 | 0 | 1 |
| | DGM/Elect. | 1 | 1 | 0 |
| | Manager/Elect | 5 | 5 | 0 |
| | AM/Elect | 7 | 4 | 3 |
| | SSE/Elect | 1 | 1 | 0 |
| | SE/Elect | 1 | 1 | 0 |
| | ASE/Elect | 10 | 10 | 0 |
| FINANCE | GM/Finance | 1 | 0 | 1 |
| | GM/F/Project | 1 | 0 | 1 |
| | JGM/Finance | 1 | 1 | 0 |
| | AM/Finance | 1 | 1 | 0 |
| | Accountant | 4 | 4 | 0 |
| ROLLING STOCK | CEE/RS_IV | 1 | 0 | 1 |
| | AGM/Electrical | 1 | 0 | 1 |
| | Dy. CEE/RS- VI | 1 | 0 | 1 |
| | Manager /KRS1 | 1 | 0 | 1 |
| | AM/KRS1 | 1 | 0 | 1 |
| | AM/NRS1 | 1 | 0 | 1 |

| Department | Position | Number of personnel | Posted at Patna | Posted at Delhi |
|---|---|---|---|---|
| TRACK | CE/Track | 1 | 0 | 1 |
| | Dy.CE/Track | 1 | 0 | 1 |
| | AEN/Track | 2 | 0 | 2 |
| | JE/Track | 4 | 0 | 4 |
| QUALITY | DGM/Quality | 1 | 1 | 0 |
| | AM/Quality | 2 | 2 | 0 |
| SAEFTY | DGM/Safety | 1 | 1 | 0 |
| | AM/Safety | 2 | 2 | 0 |
| SUM | | 174 | 120 | 54 |

Source: DMRC

### 23.6.2 Technical support

PMRCL gets overall technical support from DMRC based on the contract. PMRCL, with JICA's assistance, should define demarcation between DMRC and JICA's general consultant at the execution stage. PMRCL needs to judge if they foster its team to perform as the Employer by themselves or delegate its responsibility to DMRC while DMRC does not fulfill as GC for the JICA portion.

### 23.6.3 The necessity of technical support during construction

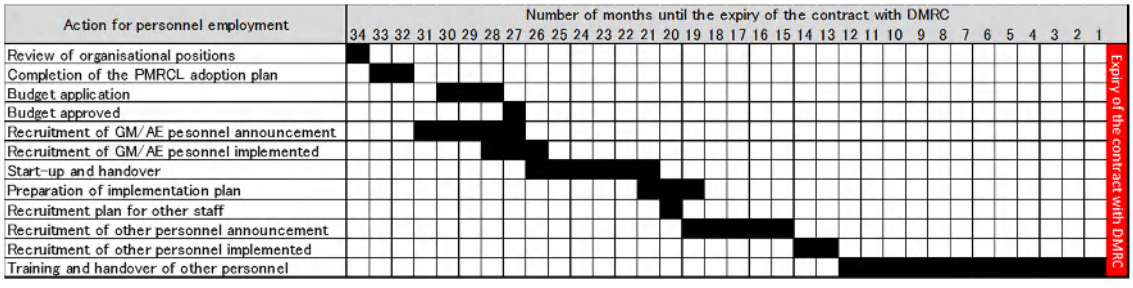
PMRCL should draw its vision after Corridor-1 and 2 construction. While the organic growth can generate valuable intangible assets, PMRCL might waste those assets unless the growth path matches the vision. As the JST acknowledges that PMRCL does not have a plan to expand its operational network and the time left to form a capable team is short, the JST suggests PMRCL should capitalize on DMRC engagement to streamline team building.

### 23.6.4 Personnel employment plan

PMRCL is currently under contract with DMRC in the implementation structure and receives a large complement of personnel from DMRC. In particular, in the technical and financial sectors, the current implementation structure is supplemented by DMRC personnel. It is necessary to plan in mid-long term for the establishment of an independent implementation and management system for PMRC in the future.

An example of a planned timeline for the employment of personnel to establish an independent implementation structure for PMRCL is given in the table below. It is expected that priority will be given to hiring GM/AE level equivalent positions in each division to build up an implementation structure.

**Table 23-9: Example of Personnel Employment Plan**




Source: JST

## 23.7 Proposed Terms of Reference for Consultant (N/A)

# 24. Operation and Maintenance (O&M)

## 24.1 Overview of Existing Studies

### 24.1.1 Organization Structure

As shown in Section 23.6, at PMRCL, only urgent posts are currently being filled and the remaining posts will be filled from time to time as per the requirement. Regarding O&M, it is noted that if PMRCL so desires, DMRC may operate and maintain the project until PMRCL has made adequate O&M arrangements. However, JST shall make suggestions on the preferred structure for PMRCL to perform its own O&M in Section 24.2.2

In the operation and maintenance of PMRCL, it is considering outsourcing housekeeping and some part of maintenance (ticketing, parking, security and allied services, maintenance of lift and escalators, and maintenance of E&M assets), but most work will be performed directly by PMRCL without outsourcing. Therefore, in considering the O&M structure and number of personnel, calculations will be made based on this assumption.

### 24.1.2 Contents of O&M Service

#### (1) Number of personnel required

In DPR, the number of personnel required for O&M is estimated at 35 persons per line kilometer, including 8 HODs, 72 Dy HODs, 48 AM/Managers, 470 supervisors, and 588 Non supervisors, for a total of 1,138 persons, but these are indicative of the scale and the exact number has not been determined at this time.

#### (2) O&M expenses (N/A)

## 24.2 Reviews of Existing Studies and Proposals for Improvement

### 24.2.1 Training

#### (1) General

The DPR does not specifically mention the training of Patna Metro personnel or its agencies.

In the Memorandum of Understanding (MOU) between DMRC and PMRCL, it is mutually agreed that several engineers will be sent to DMRC for on-the-job training and that DMRC will be responsible for training PMRCL staff from the design to the implementation and commissioning of the project.

DMRC has a state-of-the-art training facility called Delhi Metro Rail Academy (DMRA) at SHASTRI PARK depot to provide customized training on all matters required by MRTS (O&M, projects, planning and implementation), where DMRC's It is already being utilized to train not only the staff but also other Metro staff and has sufficient capacity to accommodate PMRCL trainees.

#### (2) Contents of Training

The following training has been conducted in DMRC. We believe that similar training should be conducted

in PMRCL as well. In addition to the contents of the table below, it is preferable to specifically take out and provide training in one area in addition to the contents of the table below, since ensuring safety is extremely important in all areas in railway companies.

### 1) Executives

DMRC provides customized training for the executives of the metro systems as shown in the following table, which indicates that it can organize customized training programs on various subjects related to metro technology.

**Table 24-1: Fields of training for executives**

| No | Field |
|---|---|
| 1 | Signalling system |
| 2 | Telecommunications system |
| 3 | Automatic fare collection (AFC) system |
| 4 | Electrical systems |
| 5 | Traction system |
| 6 | Tunnel ventilation system |
| 7 | Tracks |
| 8 | Rolling stock |
| 9 | Train operations |
| 10 | Metro planning |
| 11 | Finance management |
| 12 | Construction technology |

Source: PMRCL/DMRC

### 2) General workers

DMRA primarily provides training for the operations listed in Table 24-2.

**Table 24-2: Category and occupation**

| Department | Category of staff | Occupation |
|---|---|---|
| Train operation | Station controller | Responsible for station management, revenue collection, crowd management, operating the train control system from the station control room |
| | Train operator | Responsible for driving the train in accordance with the train control system, troubleshooting in the train when required, manually operating (limited mode) the train in case of any failure |
| | Customer relations assistant | Representative of the customer care centre at every station<br>Responsible for revenue related activities (ticketing), customer care, crowd management at the stations as the frontline staff directly dealing with passengers |
| Rolling stock | Supervisor (Junior engineer) | Responsible for supervising the technical servicing of rolling stock as a technical supervisory level staff |
| | Maintainer/fitter | Responsible for maintenance of rolling stock under close supervision of the concerned JE |
| Signalling | Supervisor (Junior engineer) | Responsible for supervising the technical services of signalling as a technical supervisory level staff |

| Department | Category of staff | Occupation |
|---|---|---|
| | Maintainer/fitter | Responsible for maintenance of signalling under close supervision of the concerned JE |
| Telecommunications & AFC | Supervisor (Junior engineer) | Responsible for supervising the technical services of telecommunications & AFC as a technical supervisory level staff |
| | Maintainer/fitter | Responsible for maintenance of telecommunications & AFC under close supervision of the concerned JE |
| Electrical & mechanical service | Supervisor (Junior engineer) | Responsible for supervising the technical services of electrical & mechanical service as a technical supervisory level staff |
| | Maintainer/fitter | Responsible for maintenance of electrical & mechanical service under close supervision of the concerned JE |
| Civil engineering | Supervisor (Junior engineer) | Responsible for supervising the technical services of civil engineering as a technical supervisory level staff |
| | Maintainer/fitter | Responsible for maintenance of civil engineering under close supervision of the concerned JE |

Note: Unlike a general Japanese railway, DMRC considers station controllers and train operators as the same job category and exchanges their staff periodically.

Source: JST based on DMRC data.

### (3) Training duration

The standard training periods are shown Table 24-3.

**Table 24-3: Occupation Wise Training Duration**

| | Occupational category | | Training period (week) | | | Notes |
|---|---|---|---|---|---|---|
| | | | Total | School | Practice | |
| A | Station controller<br>Train operator | | 30 | 26 | 4 | 3 signal types, 3 rolling stock types for newcomers |
| B | Train operator (Limited license) | | 19 | 15 | 4 | 1 signal type, 1 rolling stock type for newcomers |
| C | Station controller (Limited license) | | 14 | - | - | |
| C | Signal maintenance | Supervisor<br>Maintainer | 20<br>17 | 20<br>17 | -<br>- | for newcomers |
| D | E&M maintenance | Supervisor<br>Maintainer | 24<br>16 | 24<br>16 | -<br>- | |
| E | Track maintenance | Supervisor<br>Maintainer | 19<br>17 | 19<br>17 | -<br>- | |
| F | Rolling stock maintenance | Supervisor<br>Maintainer | 19<br>17 | 19<br>17 | -<br>- | |
| G | OCC | Train dispatcher | 3 | 3 | - | for experienced station controllers & train operators |

Source: PMRCL/DMRC

Of these, drivers, in particular, require a relatively long training period, so appropriate employment timing and training plans need to be planned well in advance. Table 24-4 shows the number of drivers required in the horizon year for the train operation plan described in Section 8.2 (See 24.2.2(2)2) for calculation of the required number of drivers.)

**Table 24-4: Number of drivers required in horizon year**

| | 2024 | 2031 | 2041 | 2051 |
|---|---|---|---|---|
| Corridor-1 | 46 | 56 | 55 | 61 |
| Corridor-2 | 36 | 45 | 48 | 54 |
| **TOTAL** | **82** | **101** | **103** | **115** |

Source: JST

As shown in the table above, PMRCL needs to train at least 82 new drivers by the time it opens for business. As shown in Table 24-3, driver training takes as long as 30 weeks, so it is necessary to make a recruitment plan well in advance. PMRCL plans to begin recruiting 18 months prior to the opening of the new train, which should not present any problems.

### (4) Equipment required for training

DMRA was established in December 2002, five months before DMRC's first metro section opened, and currently has 25 classrooms with a capacity of 904 students. It has 32 simulator rooms and 11 demonstration rooms for operation and maintenance training, and 62 faculty members. It has already provided training to more than 45,000 DMRC employees and more than 3,000 employees of other metros, including overseas metros, and in addition to training for general employees, it also provides management capacity building

and advanced job skills acquisition training for mid-level executives. In addition, mid- to high-level executives are trained to improve their management skills at the Management Development Institute (DMI), which has a partnership relationship with DMRC.



Source: https://dmra.delhimetrorail.com/about.html

**Figure 24-1: Exterior View of DMRA**

This training institute is equipped with the following facilities to provide practical training.

**Table 24-5: Facilities of DMRA**

1. Classrooms
2. Driving Simulators
3. Trouble-Shooting & Maintenance Simulators
4. Automatic Train Supervision [ATS] Simulator
5. CBT (Computer Based Training)
6. Traction Demonstration & OHE Yard
7. Escalator Model Room
8. Elevator
9. 33 KV Circuit Breaker Model Room
10. Civil Engineering Demonstration Room
11. True Scale Tunnel Model
12. Rigid Overhead Conductor System (OHE in Tunnel)
13. ECS/TVS Model Room
14. Operation Demonstration Room
15. S&T Demonstration Room
16. Library
17. Auditorium
18. Computer Labs
19. Tele-Presence Room
20. Training Management System (TMS)
21. Hostel and Guest House
22. Canteen
23. Holistic Development (Morning Assembly, Yoga & Meditation, Gymnasium)
24. Academy Magazine

Source: DMRC

It has been decided that the PMRCL staff training required for the opening will be conducted through DMRA, but after the opening of the PMRCL, it is expected that on-the-job training will be mainly conducted through daily operations. However, it will be necessary to accept a certain number of new employees each year in order to increase the number of employees due to the increase in transportation capacity in response to the increase in the number of users, and to fill vacancies caused by retirements. The number of personnel required by PMRCL is estimated to be 1,138, and even if they are replaced every 25 years or so, the number of new trainees is expected to average about 45 per year for the entire company in total, and at this personnel size, it would be inefficient to secure a training organization and many instructors, etc. on its own.

As for drivers, a large number of new trainers will need to be trained at once just before 2031, 2041, and 2051, when the transportation capacity is scheduled to be increased, respectively, but the number is very small compared to the number at the time of opening.

On the other hand, since PMRCL is similar in many areas to other metros in India in terms of the technology and mechanisms used, and therefore the content to be trained is expected to be generally the same, it is realistic to expect that the existing training facilities in India will continue to be used for much of the curriculum.

In the case of setting up their own training facilities, it would be necessary to devise ways to make effective use of the facilities, such as actively accepting outside trainees, as in the case of DMRA, by regarding training as a form of non-railway business income business.

Table 24-6 shows the means for O&M personnel training, including the use of DMRA, organized by department. Note that PMRCL's own training is necessary even when training is conducted under the DMRA, due to the existence of equipment specific to PMRCL and the need for on-site training.

**Table 24-6: O&M department wise means of training**

| Department | | Roles | Means of Training | | |
|---|---|---|---|---|---|
| | | | DMRA | Supported by Consulting Service | |
| | | | | Training by Contractor | Training by Instructive Experts |
| Operation | Drivers | | ● | | ● |
| | Office | | ● | | ● |
| | Station | Experts for primary instructors | ● | ● | ● |
| | | Experts for assistant manager | | ● | ● |
| | | Other station staff | | | ● |
| Maintenance | E&M | Instructive Experts | ● | ● | ● |
| | | Other maintenance staff | ● | | ● |
| | R/S | Instructive Experts | ● | ● | ● |
| | | Other maintenance staff | ● | | ● |
| | Electric | Instructive Experts | ● | ● | ● |
| | | Other maintenance staff | ● | | ● |
| | Civil | Instructive Experts | ● | ● | ● |
| | | Other maintenance staff | ● | | ● |

Source: JST

### 24.2.2 O&M Structure

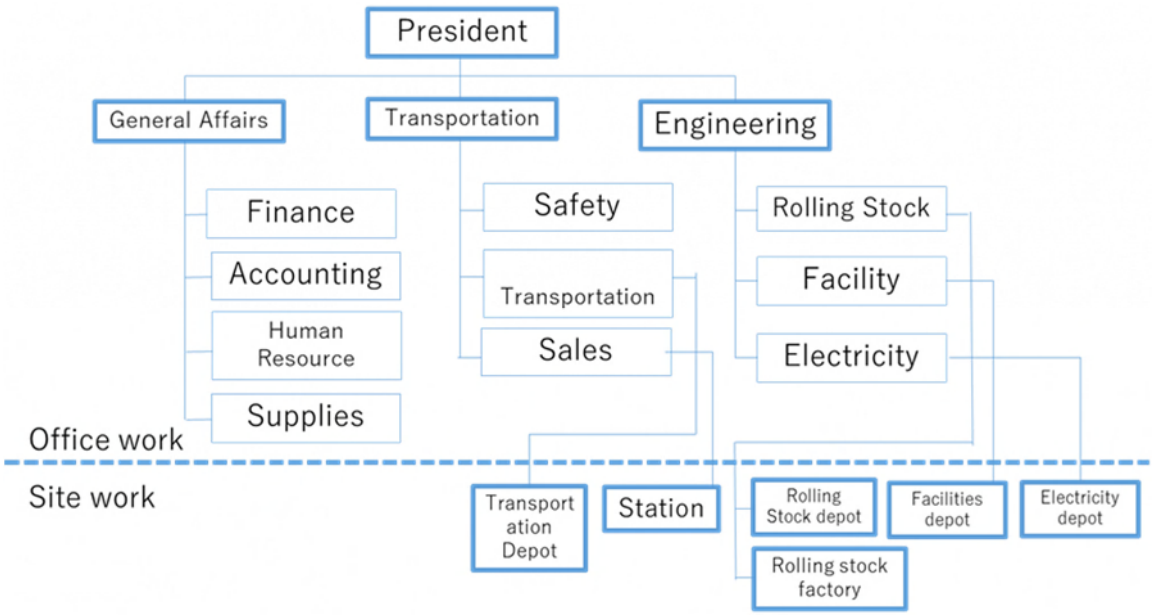
#### (1) Organization Structure

The DPR contains only the current organizational structure of PMRCL and a rough estimate of the size of future manpower requirements.

Therefore, we will examine and propose an appropriate organizational structure for O&M of PMRCL by organizing examples from India and other Southeast Asian countries.

1) General organization structure

Generally, the operating organization of a railway company is structured based on the scale of railway operations and other factors, taking into consideration the system of responsibility (job description), chain of command, and efficient operation. The general organizational structure of a railway company is divided into two parts: non-current divisions that operate and manage the corporate organization, such as general affairs, human resources, and accounting, and current divisions that perform actual operations and maintenance. The general organizational structure is shown in Figure 24-2.




Source: JST

**Figure 24-2: General Organizational Structure of Railway Companies**

The posts that PMRCL has prepared at the present time, as summarized in Section 23.6, cover each of the organizations shown in Figure 24-2, and the members assigned to these posts can be considered as the core of the O&M system after the opening of the business. Conversely, for those positions that are not fully staffed at this time, personnel should be secured as soon as possible so that they can be trained to become core members of each organization in time for the start of operations.

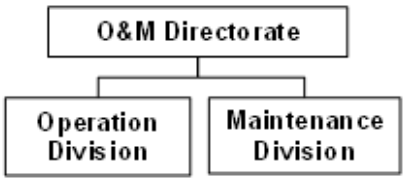
### 2) Points to focus on when considering organizational structure

The main points of focus in examining the organizational structure include the following;

- ✓ Whether the operations and maintenance departments should be part of the same organization
- ✓ Whether to place administrative departments such as finance and human resources under the operations department or to make them independent.
- ✓ Whether to place the operations organization under the head office departments or to make it independent from them.
- ✓ Whether to place non-rail divisions under the O&M department or to make them independent.

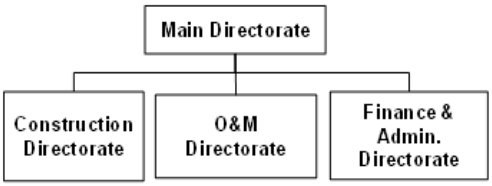
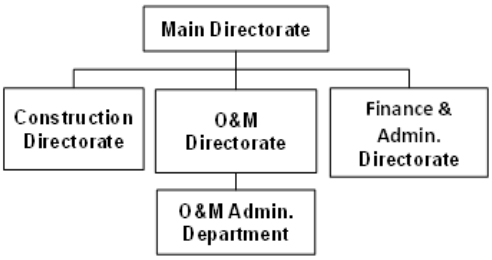
The following is a summary of the possible options and their advantages and disadvantages in each of these focus points.

**Table 24-7: O&M Departments**

| | Option 1<br>(O&M are consolidated.) | Option 2<br>(O&M are separated.) |
|---|---|---|
| Organization Chart |  |  |
| Strengths | • Easier coordination across the operation departments and maintenance departments<br>• Smaller number of personnel in total | • More focus on their own roles |
| Weaknesses | • Less focus on their own roles | • More difficult coordination across the operation departments and maintenance departments<br>• Larger number of personnel in total |

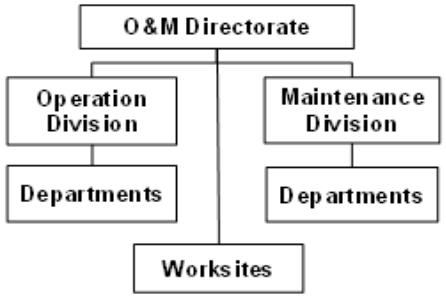
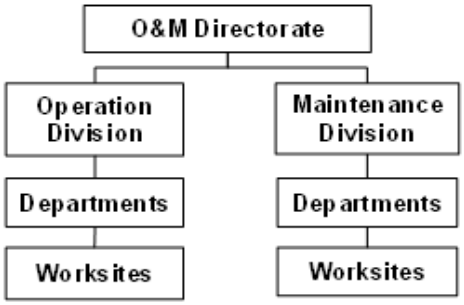
Source: JST

**Table 24-8: Administrative Units**

| | Option 1<br>(Independent Admin. Dept.) | Option 2<br>(O&M units has their own Admin. units) |
|---|---|---|
| Organization Chart |  |  |
| Strengths | • More efficient management of personnel and trainings, for the entire organization<br>• More efficient budgeting and business planning for the entire organization<br>• Smaller number of personnel in total | • More efficient management of personnel and trainings for the O&M units<br>• More efficient budgeting and business planning for the O&M units |
| Weaknesses | • Less efficient management of personnel and trainings for the O&M units<br>• Less efficient budgeting and business planning for the O&M units | • Less efficient management of personnel and trainings for the entire organization<br>• Less efficient budgeting and business planning for the entire organization<br>• Larger number of personnel in total |

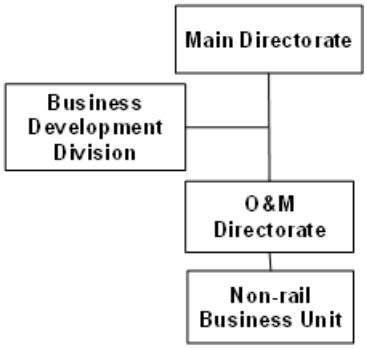
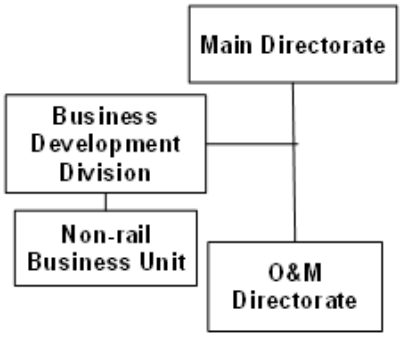
Source: JST

**Table 24-9: Worksites Reporting Structure**

| | Option 1<br>(Worksite offices are directly under the O&M Directorate) | Option 2<br>(Each worksite office is under the corresponding department in HQ) |
|---|---|---|
| Organization Chart |  |  |
| Strengths | • Worksite offices can preserve its power and independency.<br>• Opinions from frontline (i.e. worksite offices) will reach directly to the final decision maker (i.e. O&M director). | • Total manpower may be reduced as head posts of department in HQ and worksite office can be combined.<br>• Hierarchical structures and chain of commands will become clearer. |
| Weaknesses | • Total manpower may be larger.<br>• Hierarchical structures and chain of commands will become more complex. | • Worksite offices will be more dependent on departments in HQ.<br>• Opinions from frontline (i.e. worksite offices) will be buffered at departments in HQ before reaching to the final decision maker (i.e. O&M director). |

Source: JST

**Table 24-10: Location of Non-rail Business Unit**

| | Option 1<br>(Under O&M Directorate.) | Option 2<br>(Under Business Development Division) |
|---|---|---|
| Organization Chart |  |  |
| Strengths | • Support from the O&M directorate<br>• Closer to the operation worksites in order to reflect the worksites opinions easily | • Support from the business development division<br>• To establish consistency in non-rail business among planning & strategy and the main directorate decision |
| Weaknesses | • Difficulty to establish close relationship with planning & development and daily operation in non-rail business | • Heavy burden for the main directorate<br>• Weaker connectivity with O&M directorate and daily operation worksites |

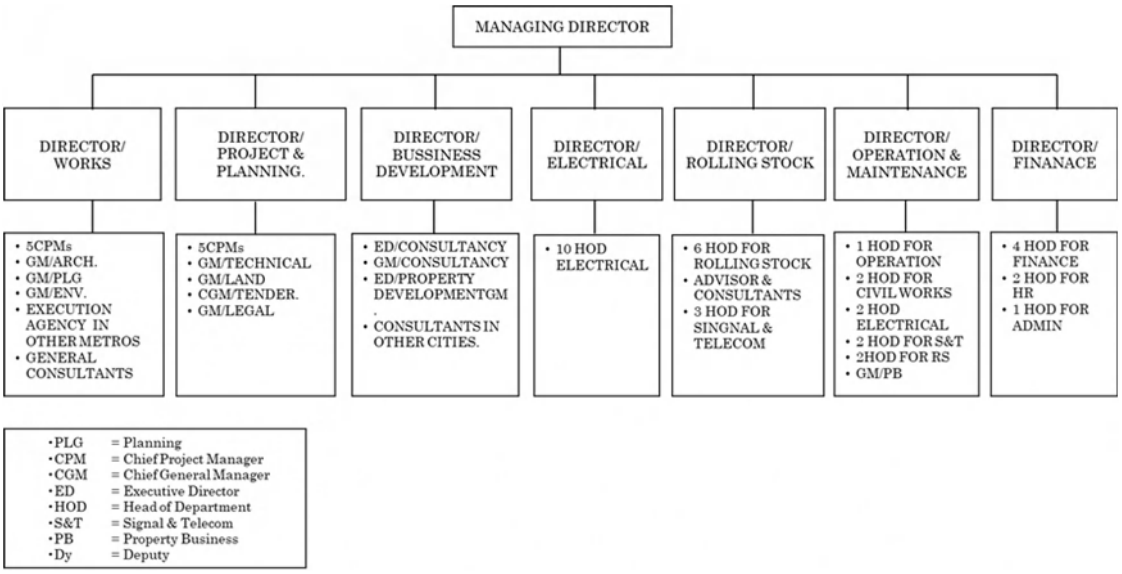
Source: JST

Since each region has different circumstances, it is advisable to determine the organizational structure after carefully analyzing what is the best structure for that region with regard to the above issues.

### 3) Case study in India

Figure 24-3 shows the organizational chart of DMRC, which operates Delhi Metro, and the functions of

each department.




Source: JST from materials received by DMRC.

**Figure 24-3: Organization of DMRC**

DMRC is comprised of seven divisions with a staff of approximately 13,500, of which approximately 12,800 are involved in O&M. Table 24-11 shows the divisions included in O&M department and the number of personnel involved.

**Table 24-11: Number of personnel in DMRC's O&M department**

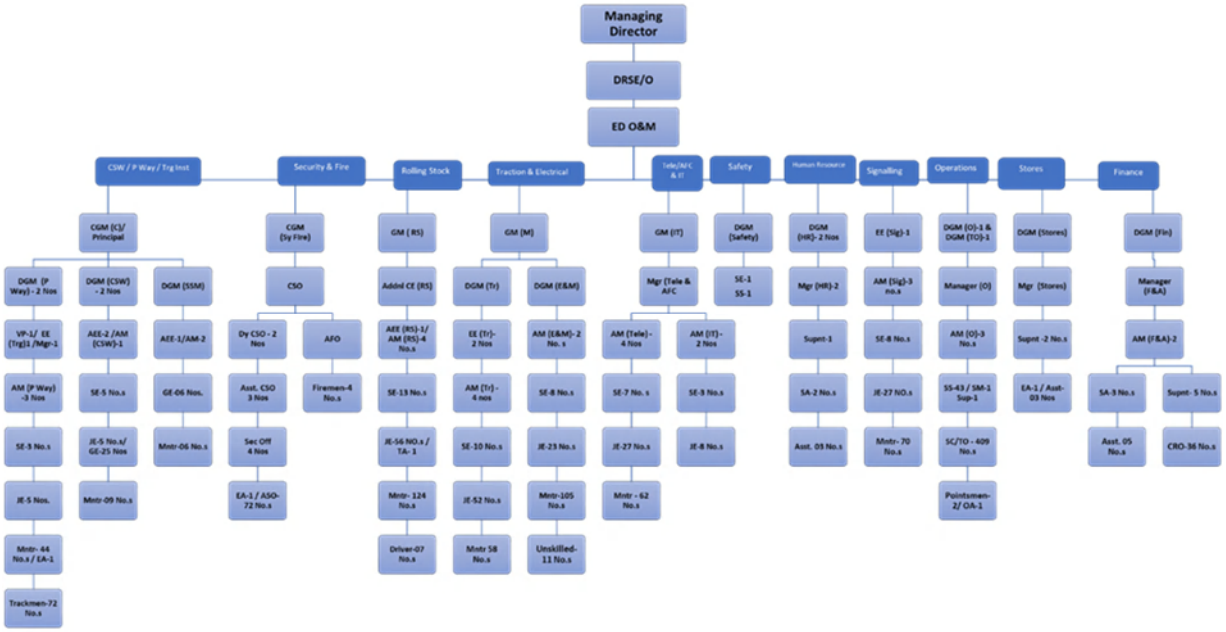
| Department | | Number of Stuff | | managerial post | | | |
|---|---|---|---|---|---|---|---|
| | | | | Executive | Sup | Non-sup | FH |
| Operation | | 4,698 | | 50 | 3,103 | 1,545 | |
| Rolling Stock | | 2,618 | | 82 | 750 | 1,786 | |
| Equipment | E&M | 1,402 | | 30 | 356 | 1,016 | |
| Electric | Traction | 3,116 | 1,041 | 28 | 237 | 776 | |
| | Signaling | | 1,102 | 29 | 325 | 748 | |
| | Telecommunication | | 973 | 29 | 286 | 658 | |
| Civil | | 563 | | 38 | 227 | 298 | |
| General | Financial | 403 | 69 | 23 | 46 | | |
| | Human Resource | | 33 | 10 | 23 | | |
| | Environment | | 13 | 7 | 6 | | |
| | Stores Development | | 96 | 15 | 36 | 15 | 30 |
| | Security | | 23 | 6 | 15 | 2 | |
| | Estate etc. | | 169 | 169 | | | |
| TOTAL | | 12,800 | | 347 | 5,410 | 6,844 | 30 |

Source: JST from materials received by DMRC.

At DMRC, operations and maintenance are grouped together as a single department, which includes administrative departments such as finance and human resources, as well as non-railway departments

such as real estate and store development. The hierarchical structure and chain of command for each department is clear.

Figure 24-4 shows an organizational chart of the O&M department of BMRCL, which operates the Bengaluru Metro.Table 24-12 also shows the breakdown of personnel in the O&M department.




Source: JST

**Figure 24-4: Organization of O&M Department of BMRCL**

**Table 24-12: Number of personnel in BMRCL's O&M department**

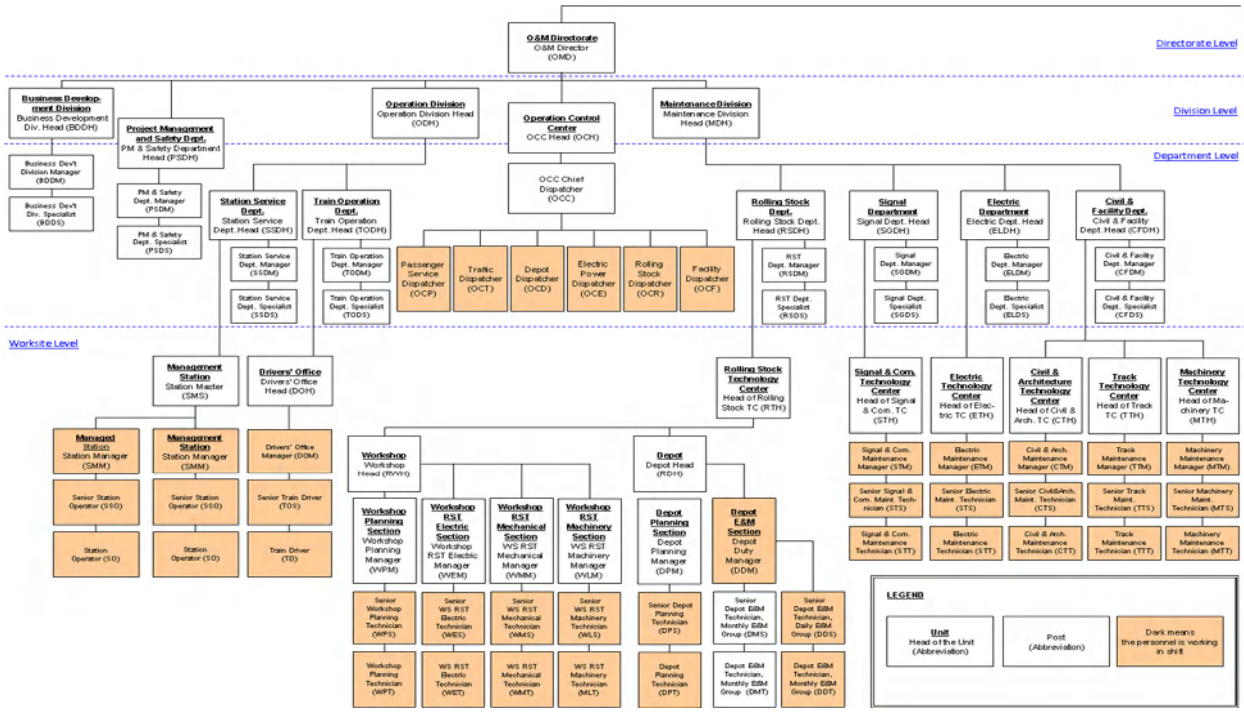
| Headquarters | | On-site organization | |
|---|---|---|---|
| Financial | 12 | Operation | 507 |
| Human Resource | 11 | Civil | 33 |
| IT | 14 | Track work | 98 |
| Venue | 7 | Signal & telecommunication | 209 |
| Security | 84 | Electric Power | 124 |
| Store Development | 34 | Rolling stock | 191 |
| Safety & others | 8 | E&M | 132 |
| **TOTAL** | **170** | **TOTAL** | **1,294** |
| **Grand TOTAL** | | | **1,464** |

Source: JST

In BMRCL, 1,464 employees (August 2020) belong to the O&M department, but as in DMRC, operations and maintenance are integrated, with administrative departments such as finance and human resources, and non-railway departments such as store development within this department. Also in BMRCL, the structure is such that the current business organization is placed under the head office functions.

### 4) Case Study in Indonesia

Figure 24-5 shows an organizational chart of MRTJ, which operates MRT in Indonesia.




Source: JST

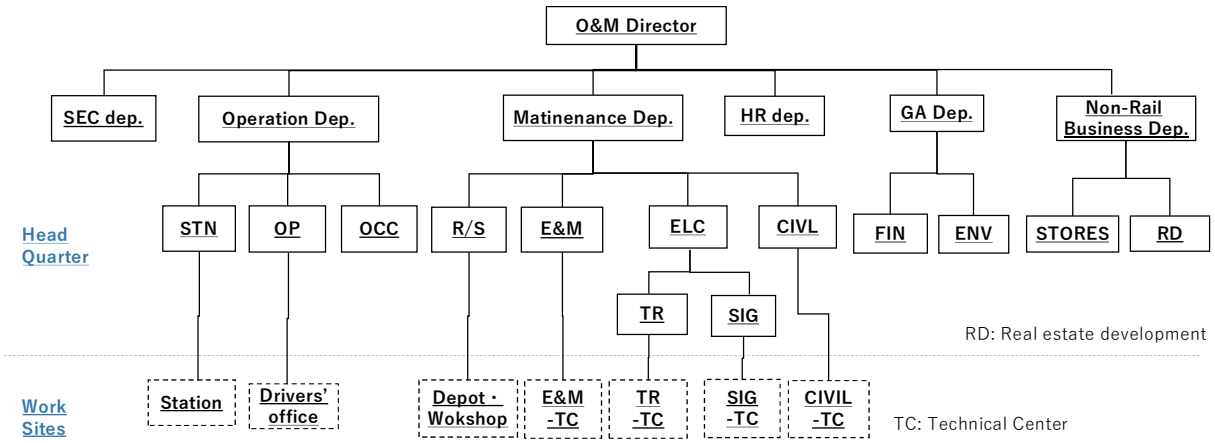
**Figure 24-5: Organization of O&M Department of MRTJ**

In MRTJ, as in DMRC and BMRCL, operations and maintenance are integrated, and non-railway departments such as store development exist within these departments. In addition, in each department, the structure is such that the current business organization is placed under the head office function.

However, administrative departments such as human resources and finance are not under O&M department, but exist as independent organizations outside O&M department. This is because MRTJ is the first metro in Indonesia and is still a young organization, so the first priority was placed on efficient financial and human resource management.

### 5) Organizational structure recommended in PMRCL

Since India already has a track record of stable subway operations in many cities, we believe that PMRCL should adopt the same organizational structure as DMRC and BMRCL. Figure 24-6 shows a framework image of the proposed organizational structure. In addition, Table 24-13 shows the proposed major division of duties for each organization.




Source: JST

**Figure 24-6: Organizational structure that we propose for PMRCL**

**Table 24-13: Proposed Major Segregation of Duties in PMRCL's O&M**

| Department/Division | | | Proposed Major Duties |
|---|---|---|---|
| Head Quarter | Safety & Security department | | Safety and cross-sectional technical management |
| | Operation Department | Station affairs | Management of station operations |
| | | Operation | Timetabling & Crew Scheduling |
| | | OCC | OCC operations, operations management, signal handling, etc. |
| | Maintenance Department | Rolling Stock | Design management and maintenance planning of rolling stocks |
| | | E&M | Maintenance plans for track and civil engineering structures |
| | | Electric | Maintenance plans for power, signalling and telecommunications equipment, and station machinery and equipment |
| | | Civil | Construction management of station improvement projects, etc. |
| | Human Resource | | Personnel management throughout O&M |
| | general affairs department | Finance | Procurement of equipment and budget management |
| | | Environment | Promote SDGs, occupational safety and health management |
| | Non-rail Business Department | Store Development | Planning and development of station-based business |
| | | Real Estate Development | Development of real estate near stations |
| Work Sites | Station | Station | Station operations such as ticket sales, passenger information, etc. |
| | Operation | Drivers' office | Management of drivers |
| | R/S | Depot | Daily rolling stock inspections and management of outsourced operations |
| | | Workshop | Heavy maintenance of rolling stocks, management of outsourcing |
| | E&M | E&M Tech. Centre | Inspection of track and civil engineering structures, management of outsourcing |
| | Electrical | Electrical Traction Tech. Centre | Inspection of electric power & traction facilities and management of outsourcing |
| | | SIG & TEL Tech. Centre | Inspection of signalling and telecommunications equipment, management of outsourcing |
| | Civil | Civil Tech. Centre | Inspection of station machinery and equipment, supervision of station improvement work, etc., and management of outsourcing |

Source: JST

## (2) Verification of the number of personnel

### 1) Number of personnel per department

In the DPR, the number of personnel required for O&M is estimated at 35 persons per line kilometer, for a total of 1,138 persons, which is the same thought in the DMRC. Therefore, we first verify whether the personnel composition of DMRC shown in Table 24-11 is appropriate by comparing it with that of Japanese subway operators.

Table 24-14 shows the results of a comparison of Japanese subway operators and DMRC in terms of the percentage of staff when categorized into administration, transportation, and maintenance.

**Table 24-14: Comparison of Personnel Composition between Japanese subway Operators and DMRC**

| Business Entity | Number of personnel | | | | Percentage of each division | | |
|---|---|---|---|---|---|---|---|
| | Operation | Maintenance | Others | TOTAL | Operation | Maintenance | Others |
| Tokyo Metro | 6,642 | 2,673 | 470 | 9,785 | 67.9 | 27.3 | 4.8 |
| Sapporo city | 317 | 139 | 84 | 540 | 58.7 | 25.7 | 15.6 |
| Sendai city | 259 | 138 | 34 | 431 | 60.1 | 32.0 | 7.9 |
| Tokyo Metropolitan | 2,201 | 1,107 | 152 | 3,460 | 63.6 | 32.0 | 4.4 |
| Yokohama city | 594 | 324 | 47 | 965 | 61.6 | 33.6 | 4.9 |
| Nagoya city | 1,681 | 880 | 157 | 2,718 | 61.8 | 32.4 | 5.8 |
| Kyoto city | 440 | 163 | 54 | 657 | 67.0 | 24.8 | 8.2 |
| Osaka Metro | 3,214 | 1,525 | 236 | 4,975 | 64.6 | 30.7 | 4.7 |
| Kobe city | 341 | 164 | 69 | 574 | 59.4 | 28.6 | 12.0 |
| Fukuoka city | 336 | 188 | 50 | 574 | 58.5 | 32.8 | 8.7 |
| (1) Total/Average | **16,025** | **7,301** | **1,353** | **24,679** | **64.9** | **29.6** | **5.5** |
| **DMRC** | **4,806** | **7,699** | **403** | **12,908** | **37.2** | **59.6** | **3.1** |
| Triple the personnel of maintenance in (1) | 16,025 | 21,903 | 1,353 | 39,281 | 40.8 | 55.8 | 3.4 |

Source: Compiled by JST from the Ministry of Land, Infrastructure, Transport and Tourism: Annual Report on Railway Statistics (2019), and materials provided by DMRC.

The table above shows that the ratio of maintenance personnel is much larger in DMRC than in Japan.

This is thought to be because the DMRC assumes direct management, while in Japan most of the actual work at maintenance sites is outsourced and only supervisors are directly managed. If maintenance personnel war directly managed in Japan, the number of required maintenance personnel would need to be three to four times larger.

Therefore, the staffing ratios in DMRC are considered to be generally appropriate.

Next, Table 24-15 compares Japanese subway operators and DMRC with respect to the ratio of the number of personnel on site in the maintenance department.

**Table 24-15: Comparison of personnel composition between Japanese subway operators and DMRC in the maintenance sector**

| Business Entity | Number of personnel on-site sector in the maintenance department | | | | Percentage of each division | | | |
|---|---|---|---|---|---|---|---|---|
| | E&M | Electric | R/S | Civil | E&M | Electric | R/S | Civil |
| Tokyo Metro | 390 | 695 | 1,015 | 98 | 18 | 32 | 46 | 4 |
| Sapporo city | 0 | 0 | 71 | 0 | 0 | 0 | 100 | 0 |
| Sendai city | 31 | 47 | 36 | 24 | 22 | 34 | 26 | 17 |
| Tokyo Metropolitan | 244 | 342 | 316 | 0 | 27 | 38 | 35 | 0 |
| Yokohama city | 84 | 72 | 47 | 3 | 41 | 35 | 23 | 1 |
| Nagoya city | 209 | 167 | 324 | 0 | 30 | 24 | 46 | 0 |
| Kyoto city | 15 | 41 | 57 | 0 | 13 | 36 | 50 | 0 |
| Osaka Metro | 290 | 413 | 562 | 47 | 22 | 31 | 43 | 4 |
| Kobe city | 33 | 60 | 49 | 0 | 23 | 42 | 35 | 0 |
| Fukuoka city | 14 | 26 | 33 | 11 | 17 | 31 | 39 | 13 |
| **Total/Average** | **1,310** | **1,863** | **2,510** | **183** | **22** | **32** | **43** | **3** |
| **DMRC** | **1,402** | **3,116** | **2,618** | **563** | **18** | **40** | **34** | **7** |

Source: Compiled by JST from the Ministry of Land, Infrastructure, Transport and Tourism: Annual Report on Railway Statistics (2019), and materials provided by DMRC.

From Table 24-15, the staffing ratios for each department of DMRC are about the same as the average figure for Japanese operators, and the number of personnel in the maintenance department provided by DMRC is also considered to be about reasonable.

Table 24-16 shows the number of personnel and their ratios for each department in the working organization of the transportation division of Japanese subway operators. The table also shows the ratio when the number of conductors is set to zero, since DMRC operates as a one-man operation and does not require conductors.

**Table 24-16: Number and Percentage of Personnel by Department on worksite organizations of Japanese subway operators**

| Business Entity | Number of personnel on-site sector in the operation department | | | | Percentage of each division | | | |
|---|---|---|---|---|---|---|---|---|
| | driver | conductor | station | others | driver | conductor | station | others |
| Tokyo Metro | 1,446 | 963 | 3,314 | 670 | 23 | 15 | 52 | 10 |
| Sapporo city | 198 | 0 | 96 | 3 | 67 | 0 | 32 | 1 |
| Sendai city | 105 | 0 | 100 | 25 | 46 | 0 | 43 | 11 |
| Tokyo Metropolitan | 647 | 234 | 1,053 | 181 | 31 | 11 | 50 | 9 |
| Yokohama city | 208 | 0 | 256 | 105 | 37 | 0 | 45 | 18 |
| Nagoya city | 492 | 99 | 422 | 627 | 30 | 6 | 26 | 38 |
| Kyoto city | 165 | 27 | 208 | 19 | 39 | 6 | 50 | 5 |
| Osaka Metro | 687 | 408 | 1,909 | 0 | 23 | 14 | 64 | 0 |
| Kobe city | 132 | 70 | 118 | 9 | 40 | 21 | 36 | 3 |
| Fukuoka city | 109 | 0 | 76 | 110 | 37 | 0 | 26 | 37 |
| Total/Average | 4,189 | 1,801 | 7,552 | 1,749 | 27 | 12 | 49 | 11 |
| **Without conductors** | **4,189** | **-** | **7,552** | **1,749** | **31** | **-** | **56** | **13** |

Source: Compiled by JST from the Ministry of Land, Infrastructure, Transport and Tourism: Annual Report on Railway Statistics (2019), and materials provided by DMRC.

Regarding PMRCL's 1,138 personnel in 2024 as indicated in the DPR, PMRCL has received a response that they have not studied the details of the breakdown by department.

On the other hand, assuming that the percentages in Table 24-14 and Table 24-15 at DMRC and the percentages of personnel per department within the transportation sector are the same as in Japan, Table 24-16 can be used to estimate the number of personnel per department at PMRCL.

Thus we obtained an estimatede number of personnel by department in PMRCL's opening year (2024). The results are shown in Table 24-17.

**Table 24-17: Estimated number of personnel needed by department in DMRC and PMRCL (2024)**

| Department | | DMRC | PMRCL | Remark |
|---|---|---|---|---|
| general affairs | | 403 | 36 | |
| Operation | Drivers | 1,492 | 132 | including internal workers at the headquarters and at the on-site organization. |
| | Station | 2,691 | 237 | |
| | Others | 623 | 55 | |
| | **Total** | **4,806** | **424** | |
| Maintenance | E&M | 1,402 | 124 | ditto |
| | R/S | 3,116 | 275 | |
| | Electric | 2,618 | 231 | |
| | Civil | 563 | 50 | |
| | **Total** | **7,699** | **679** | |
| **Grand Total** | | **12,908** | **1,138** | |

Source: JST

Approximately 66% of the personnel in the operation departments in Table 24-17 are professionals, and if we assume that these are all drivers and the same percentage is assumed for PMRCL, then the number of drivers needed at the start of operations in 2024 will be around 88.

### 2) Number of drivers required

This section attempts to calculate the number of drivers required for the train operation plan proposed in Section 8.2 from the total labor hours estimated from the total train running time.

Table 24-18 and Table 24-19 show the number of trains operated by time of day on Corridor-1 and Corridor-2 in the DPR and JICA survey team's proposed train operation plans.

**Table 24-18: Number of trains in operation by time of day as proposed by DPR and JICA Survey Team (Corridor-1)**

| Time Zone | | 2024 | | | | 2031 | | | | 2041 | | | | 2051 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DPR | | JST | | DPR | | JST | | DPR | | JST | | DPR | | JST | |
| From | To | 3cars | 6cars | 3cars | 6cars | 3cars | 6cars | 3cars | 6cars | 3cars | 6cars | 3cars | 6cars | 3cars | 6cars | 3cars | 6cars |
| 5 | 6 | 3 | 1 | 4 | 0 | 2 | 3 | 0 | 4 | 2 | 3 | 0 | 4 | 1 | 5 | 0 | 4 |
| 6 | 7 | 8 | 1 | 8 | 0 | 4 | 5 | 0 | 10 | 4 | 6 | 0 | 10.25 | 2 | 9 | 0 | 12 |
| 7 | 8 | 8 | 2 | 8.3 | 1.7 | 5 | 7 | 1.7 | 10.3 | 5 | 8 | 0 | 12 | 2 | 12 | 0 | 13.5 |
| **8** | **9** | **11** | **3** | **8.6** | **3.4** | **7** | **10** | **5** | **10** | **7** | **11** | **0** | **13.5** | **3** | **17** | **0** | **15** |
| **9** | **10** | **11** | **3** | **8.6** | **3.4** | **7** | **10** | **5** | **10** | **7** | **11** | **0** | **13.5** | **3** | **17** | **0** | **15** |
| 10 | 11 | 9 | 2 | 8.3 | 1.7 | 6 | 8 | 1.7 | 10.3 | 6 | 9 | 0 | 12 | 2 | 14 | 0 | 13.5 |
| 11 | 12 | 7 | 2 | 8 | 0 | 4 | 6 | 0 | 10 | 4 | 7 | 0 | 10.25 | 2 | 10 | 0 | 12 |
| 12 | 13 | 6 | 2 | 8 | 0 | 4 | 5 | 0 | 10 | 4 | 6 | 0 | 10.25 | 2 | 9 | 0 | 12 |
| 13 | 14 | 3 | 1 | 8 | 0 | 2 | 3 | 0 | 10 | 2 | 3 | 0 | 10.25 | 1 | 5 | 0 | 12 |
| 14 | 15 | 6 | 2 | 8 | 0 | 4 | 5 | 0 | 10 | 4 | 6 | 0 | 10.25 | 2 | 9 | 0 | 12 |
| 15 | 16 | 7 | 2 | 8 | 0 | 4 | 6 | 0 | 10 | 4 | 7 | 0 | 10.25 | 2 | 10 | 0 | 12 |
| 16 | 17 | 9 | 2 | 8.3 | 1.7 | 6 | 8 | 1.7 | 10.3 | 6 | 9 | 0 | 12 | 2 | 14 | 0 | 13.5 |
| **17** | **18** | **11** | **3** | **8.6** | **3.4** | **7** | **10** | **5** | **10** | **7** | **11** | **0** | **13.5** | **3** | **17** | **0** | **15** |
| **18** | **19** | **11** | **3** | **8.6** | **3.4** | **7** | **10** | **5** | **10** | **7** | **11** | **0** | **13.5** | **3** | **17** | **0** | **15** |
| 19 | 20 | 9 | 2 | 8.3 | 1.7 | 6 | 8 | 1.7 | 10.3 | 6 | 9 | 0 | 12 | 2 | 14 | 0 | 13.5 |
| 20 | 21 | 8 | 2 | 8 | 0 | 5 | 7 | 0 | 10 | 5 | 8 | 0 | 10.25 | 2 | 12 | 0 | 12 |
| 21 | 22 | 7 | 2 | 8 | 0 | 4 | 6 | 0 | 10 | 4 | 7 | 0 | 10.25 | 2 | 10 | 0 | 12 |
| 22 | 23 | 6 | 2 | 6 | 0 | 4 | 5 | 0 | 8 | 4 | 6 | 0 | 8 | 2 | 9 | 0 | 8 |
| 23 | 24 | 3 | 1 | 4 | 0 | 2 | 3 | 0 | 4 | 2 | 3 | 0 | 4 | 1 | 5 | 0 | 4 |
| **Total** | | **143** | **38** | **145.6** | **20.4** | **90** | **125** | **26.8** | **177.2** | **90** | **141** | **0** | **200** | **39** | **215** | **0** | **226** |
| Peak (/h) | | 11 | 3 | 8.6 | 3.4 | 7 | 10 | 5 | 10 | 7 | 11 | 0 | 13.5 | 3 | 17 | 0 | 15 |
| Daytime (/h) | | 3 | 1 | 8 | 0 | 2 | 3 | 0 | 10 | 2 | 3 | 0 | 10.25 | 1 | 5 | 0 | 12 |

Source: DPR & JST

**Table 24-19: Number of trains in operation by time of day as proposed by DPR and JICA Survey Team (Corridor-2)**

| Time Zone | | 2024 | | 2031 | | 2041 | | 2051 | |
|---|---|---|---|---|---|---|---|---|---|
| | | DPR | JST | DPR | JST | DPR | JST | DPR | JST |
| From | To | 3cars | 3cars | 3cars | 3cars | 3cars | 3cars | 3cars | 3cars |
| 5 | 6 | 4 | 4 | 5 | 4 | 5 | 4 | 6 | 4 |
| 6 | 7 | 7 | 8 | 9 | 10 | 9 | 10 | 10 | 12 |
| 7 | 8 | 9 | 10 | 12 | 12 | 13 | 13 | 14 | 16 |
| **8** | **9** | **13** | **12** | **17** | **16** | **18** | **18.5** | **20** | **20** |
| **9** | **10** | **13** | **12** | **17** | **16** | **18** | **18.5** | **20** | **20** |
| 10 | 11 | 10 | 10 | 14 | 12 | 14 | 13 | 16 | 16 |
| 11 | 12 | 8 | 8 | 10 | 10 | 11 | 10 | 12 | 12 |
| 12 | 13 | 7 | 8 | 9 | 10 | 9 | 10 | 10 | 12 |
| 13 | 14 | 4 | 8 | 5 | 10 | 5 | 10 | 6 | 12 |
| 14 | 15 | 7 | 8 | 9 | 10 | 9 | 10 | 10 | 12 |
| 15 | 16 | 8 | 8 | 10 | 10 | 11 | 10 | 12 | 12 |
| 16 | 17 | 10 | 10 | 14 | 12 | 14 | 13 | 16 | 16 |
| **17** | **18** | **13** | **12** | **17** | **16** | **18** | **18.5** | **20** | **20** |
| **18** | **19** | **13** | **12** | **17** | **16** | **18** | **18.5** | **20** | **20** |
| 19 | 20 | 10 | 10 | 14 | 12 | 14 | 13 | 16 | 16 |
| 20 | 21 | 9 | 8 | 12 | 10 | 13 | 10 | 14 | 12 |
| 21 | 22 | 8 | 8 | 10 | 10 | 11 | 10 | 12 | 12 |
| 22 | 23 | 7 | 6 | 9 | 8 | 9 | 8 | 10 | 8 |
| 23 | 24 | 4 | 4 | 5 | 4 | 5 | 4 | 6 | 4 |
| **Total** | | **164** | **166** | **215** | **208** | **224** | **222** | **250** | **256** |
| Peak (/h) | | 13 | 12 | 17 | 16 | 18 | 18.5 | 20 | 20 |
| Daytime (/h) | | 4 | 8 | 5 | 10 | 5 | 10 | 6 | 12 |

Source: DPR & JST

As shown in Section 8.2, the one-way trip times for Corridor-1 and 2 are 32 minutes and 24.5 minutes, respectively, and assuming a minimum turnaround time of 3 minutes at the terminus station, whether at the stabling line or at the platform, the minimum round-trip trip times for Corridor-1 and 2 are 70 minutes and 55 minutes, respectively.

The number of rakes required for each time zone is calculated from dividing the minimum round trip time by the headway and converting to an integer. Table 24-20 shows the required number of rakes in the horizon year using the same method.

**Table 24-20: Number of rakes required in the horizon year (proposed by JST)**

| Item | Corridor-1 | | | | | | | | Corridor-2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2024 | | 2031 | | 2041 | | 2051 | | 2024 | 2031 | 2041 | 2051 |
| | 3cars | 6cars | 3cars | 6cars | 3cars | 6cars | 3cars | 6cars | 3cars | | | |
| Peak train number | 8.6 | 3.4 | 5 | 10 | 0 | 13.5 | 0 | 15 | 12 | 16 | 18.5 | 20 |
| Headway (min) | 7.0 | 17.6 | 12.0 | 6.0 | - | 4.4 | - | 4.0 | 5.0 | 3.8 | 3.2 | 3.0 |
| Minimum round trip time (min) | 70.0 | | | | | | | | 55.0 | | | |
| Required rakes | 10 | 4 | 6 | 12 | 0 | 16 | 0 | 18 | 11 | 15 | 17 | 19 |

Source: JST

Next, the number of crew members needed is determined by adding up the total hours worked on the trains listed in Table 24-18 and Table 24-19. The results are shown in Table 24-21.

The concepts and assumptions used in the calculations in Table 24-21 are as follows;

- ✓ The total working hours of commercial train (⑤) is the sum of train hours (③) and estimate train-watching times (④).
- ✓ During shunting, the driver does not need to be in the cab, but is required to spend train-watching times (④). The average time of train-watching times is assumed to be 4 minutes per one-way trip.
- ✓ The difference between the number of rakes required during peak and daytime hours is equal to the number of trains entering to depot and leaving from depot before and after daytime hours. The driver is responsible for these in-and-out depot operations (⑥)
- ✓ Assume that rakes on Corridor-1 enter and leave the depot by out-of-service trains through Corridor-2. One out-of-service trains is expected to operate between Khemni Chak and New ISBT in 7 minutes. (⑦)
- ✓ Total driving hours (⑧) is the sum of total working hours of commercial train (⑤) and time for out-of-service trains (⑦).
- ✓ The following other than train driving hours are assumed to be counted as working hours for drivers (⑨)
  - Time to get ready for work: 30 minutes per one journey of crew
  - Walking time: 30 minutes per one journey of crew on average
  - Preparation time when arrive at depot: 30 minutes per arrive
  - Preparation time when departure from depot: 20 minutes per departure
- ✓ Total duty hours (⑩) is the sum of total driving hours (⑧) and other than train driving hours (⑨).
- ✓ Assuming that each person works 8 hours/day (⑪), the minimum number of employees required (⑫) is calculated.
- ✓ Assumes that in addition to the driver of the mainline train, two drivers per day each are required to shunt in the Depot (⑬) and for driving the maintenance cars (⑭).

- ✓ Minimum number of personnel per day (⑮) is the sum of ⑫ to ⑭.
- ✓ Assuming 80 days off per year and 365.25 total working days per year, the minimum number of holiday equivalent personnel is calculated (⑯)
- ✓ The total number of personnel (⑰) is the sum of the minimum number of personnel per day (⑮) and the minimum number of holiday equivalent personnel (⑯).
- ✓ Assuming that the overall margin ratio (⑱) is 5%, the number of personnel required (⑲) is calculated.
- ✓ The number of drivers required is the integer of ⑲ (⑳).

**Table 24-21: Calculation of the Number of drivers required in horizon year**

| Item | | Unit | Corridor-1 | | | | Corridor-2 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 2024 | 2031 | 2041 | 2051 | 2024 | 2031 | 2041 | 2051 |
| ① | Number of trains per day, one-way | /day | 166 | 204 | 200 | 226 | 166 | 208 | 222 | 256 |
| ② | One-way trip time | hour | 0.533 | 0.533 | 0.533 | 0.533 | 0.408 | 0.408 | 0.408 | 0.408 |
| ③ | Total train running time (Train hours) | h/day | 177.1 | 217.6 | 213.3 | 241.1 | 135.6 | 169.9 | 181.3 | 209.1 |
| ④ | Estimate train-watching times | h/day | 8.3 | 10.2 | 10.0 | 11.3 | 8.3 | 10.4 | 11.1 | 12.8 |
| ⑤ | Total working hours of commercial train | h/day | 185.4 | 227.8 | 223.3 | 252.4 | 143.9 | 180.3 | 192.4 | 221.9 |
| ⑥ | Number of in-and-out depot operations | /day | 18 | 24 | 20 | 22 | 14 | 20 | 24 | 27 |
| ⑦ | Total time for out-of-service trains | h/day | 4.2 | 5.6 | 4.7 | 5.1 | 0.0 | 0.0 | 0.0 | 0.0 |
| ⑧ | Total driving hours | h/day | 189.6 | 233.4 | 228.0 | 257.5 | 143.9 | 180.3 | 192.4 | 221.9 |
| ⑨ | Other than train driving hours | h/day | 48.8 | 63.2 | 63.3 | 69.7 | 37.3 | 51.7 | 56.2 | 63.3 |
| ⑩ | Total duty hours | h/day | 238.4 | 296.6 | 291.3 | 327.2 | 181.2 | 231.9 | 248.6 | 285.2 |
| ⑪ | Working hours per person per day | h/day | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 |
| ⑫ | Min. number of employees required | person | 29.8 | 37.1 | 36.4 | 40.9 | 22.7 | 29.0 | 31.1 | 35.7 |
| ⑬ | Drivers for shunt in the Depot per day | person | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| ⑭ | Drivers for the maintenance cars | person | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| ⑮ | Min. number of personnel per day | person | 33.8 | 41.1 | 40.4 | 44.9 | 26.7 | 33.0 | 35.1 | 39.7 |
| ⑯ | Min. number of holiday equivalent personnel | person | 9.5 | 11.5 | 11.3 | 12.6 | 7.5 | 9.3 | 9.8 | 11.1 |
| ⑰ | Total number of personnel | person | 43.3 | 52.6 | 51.8 | 57.5 | 34.1 | 42.2 | 44.9 | 50.8 |
| ⑱ | Overall margin ratio | person | 5% | 5% | 5% | 5% | 5% | 5% | 5% | 5% |
| ⑲ | The number of personnel required (incl. margin) | person | 45.4 | 55.2 | 54.3 | 60.4 | 35.8 | 44.4 | 47.2 | 53.3 |
| ⑳ | **The number of drivers required (conversion to an integer)** | | **46** | **56** | **55** | **61** | **36** | **45** | **48** | **54** |
| **Total number of personnel for Corridor-1&2** | | | **82** | **101** | **103** | **115** | | | | |

Source: JST

According to Table 24-21 the number of drivers required at PMRCL was generally calculated to be 82 persons in 2024, 101 persons in 2031, 103 persons in 2041, and 115 persons in 2051.

This result is almost consistent with the number of drivers obtained in 1).

Therefore, the number of drivers determined both in this section and in 1) are also considered to be generally appropriate.

### 3) Hiring and training plan for O&M personnel

As shown in Table 24-17, since a large number of personnel will need to be hired and trained before the opening of O&M, a plan for hiring and training personnel should be made well in advance. For training, we suggest making maximum use of the DMRA as shown in Table 24-6. Table 24-22 shows a proposed approximate timeline and training plan for hiring by O&M department, based on examples from metro operators in other countries.

In particular, it is common for a small number of people to be trained for a long period of time for driver training, and a delay in the training period could result in the inability to operate the trains. We suggest that a more detailed employment and training plan be formulated as soon as possible.

In addition, when hiring, it should be noted that PMRCL is also obligated by the central government to achieve a 30% female ratio, as noted in Section 15.14, and must employ at least 30% women.

## Table 24-22: Proposed plan to hire and train O&M personnel

| Department | | Number of Personnel: Total | from implemetation Structure | New hires needed | | Roles | Means of Training: DMRA | Supproted by Consulting Service: Training by Contractor | Training by Instrucive Experts | Deadline of hiring (Months before opening) | Number of months until opening: 18 | 17 | 16 | 15 | 14 | 13 | 12 | 11 | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Operation | Drivers | 132 | 0 | 132 | 12 | Supervising driver #1 | ● | | ● | 16 | | | | | | | | | | | | | | | | | | |
| | | | | | 10 | Supervising driver #2 | ● | | ● | 15 | | | | | | | | | | | | | | | | | | |
| | | | | | 10 | driver #3 | ● | | ● | 14 | | | | | | | | | | | | | | | | | | |
| | | | | | 10 | driver #4 | ● | | ● | 13 | | | | | | | | | | | | | | | | | | |
| | | | | | 10 | driver #5 | ● | | ● | 12 | | | | | | | | | | | | | | | | | | |
| | | | | | 10 | driver #6 | ● | | ● | 11 | | | | | | | | | | | | | | | | | | |
| | | | | | 10 | driver #7 | ● | | ● | 10 | | | | | | | | | | | | | | | | | | |
| | | | | | 10 | driver #8 | ● | | ● | 9 | | | | | | | | | | | | | | | | | | |
| | Office Worker | | | | 25 | office worker#1 | ● | | ● | 9 | | | | | | | | | | | | | | | | | | |
| | | | | | 25 | office worker#2 | ● | | ● | 7 | | | | | | | | | | | | | | | | | | |
| | Station | 237 | 0 | 237 | 15 | Experts for primary instructors | ● | ● | ● | 12 | | | | | | | | | | | | | | | | | | |
| | | | | | 40 | Experts for assistant manager | | ● | ● | 9 | | | | | | | | | | | | | | | | | | |
| | | | | | 182 | Other station staff | | | ● | 6 | | | | | | | | | | | | | | | | | | |
| Maintenance | E&M | 124 | 18 | 106 | 15 | Instructive Experts | ● | ● | ● | 14 | | | | | | | | | | | | | | | | | | |
| | | | | | 91 | Other maintenance staff | ● | | ● | 9 | | | | | | | | | | | | | | | | | | |
| | R/S | 275 | 18 | 257 | 20 | Instructive Experts | ● | ● | ● | 14 | | | | | | | | | | | | | | | | | | |
| | | | | | 237 | Other maintenance staff | ● | | ● | 9 | | | | | | | | | | | | | | | | | | |
| | Electric | 231 | 27 | 204 | 20 | Instructive Experts | ● | ● | ● | 14 | | | | | | | | | | | | | | | | | | |
| | | | | | 184 | Other maintenance staff | ● | | ● | 9 | | | | | | | | | | | | | | | | | | |
| | Civil | 50 | 34 | 16 | 10 | Instructive Experts | ● | ● | ● | 14 | | | | | | | | | | | | | | | | | | |
| | | | | | 6 | Other maintenance staff | ● | | ● | 9 | | | | | | | | | | | | | | | | | | |

Remark: It is assumed that personnel will be shifted from the implementation structure to the General Affairs Department and other departments of the operation. (91 people in total)

Source:JST

Legend: hiring; Training at DMRA; Training by Contractor; Training by Instrucor

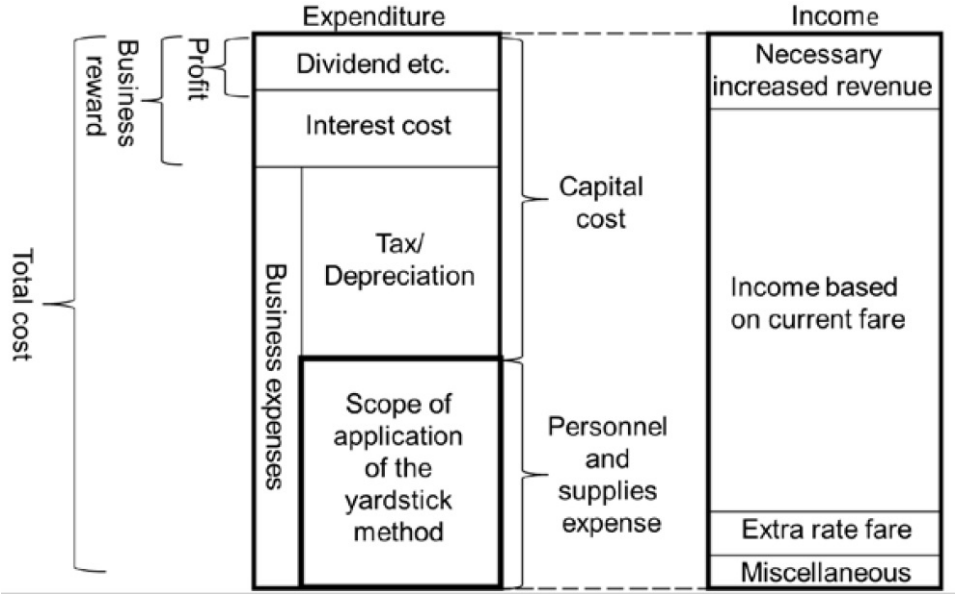
### (3) Verification of O&M costs

In Japan, the Railway Business Act regulates maximum fares based on the overall cost of railroad operations. The yardstick method is used to calculate labor costs and expenses in the total cost of railway operations by multiplying the standard unit price, which is revised annually by the Ministry of Land, Infrastructure, Transport and Tourism, by the amount of facilities of the railway operator to calculate the operator's standard cost. The standard unit cost obtained by the regression formula for the railway operator group to which the operator belongs can be regarded as the average maintenance cost for that operator group, and we will attempt to calculate O&M costs for Patna Metro based on this.

#### 1) Overview of Yardstick Method

The total cost of railway operations is defined as the appropriate cost plus an appropriate profit margin. Personnel costs and expenses are classified into five categories (route costs, electric line costs, rolling stock costs, train operating costs, and station service costs), and the standard unit costs for each category are calculated using regression equations. The regression formulas are based on the actual unit costs of each railway operator group with similar business conditions, and are published annually by the Ministry of Land, Infrastructure, Transport and Tourism. There are three groups of railway companies: six JR passenger carriers, 15 major private railway companies, and 10 subway companies.

The standard unit price derived from the regression equation is the average unit price of the operator groups, and if the total cost of the railway operator calculated based on this is higher than the current revenue, fare revision is allowed. On the other hand, if the total cost is less than the current revenue, fare revision is not allowed. This has the effect of encouraging railway operators that wish to revise fares to improve management efficiency. Figure 24-7 shows the scope of application of the yardstick method.




Source: Ministry of Land, Infrastructure, Transport and Tourism (MLIT)

**Figure 24-7: Scope of application of Yardstick Method**

### 2) Calculation of standard unit price and standard cost

#### a) Transportation and facility volume

Table 24-23 shows transport volumes and facilities owned by Japanese subway operators and Patna Metro. For reference purposes, the table also includes values for Mumbai Metro Line 3 (MM3), a recent example of similar scale in India.

Most of the values for Patna Metro refer to the 2024 values listed in the DPR, but the line extensions were calculated by adding the line length for the double track plus the line extensions into and out of the depots. For train line extension, feeder line extension, transmission line extension, and distribution line extension, which are not listed in the DPR, calculations are based on the assumption that the ratio of line length to each extension is the same as that in MM3. The average trip length of 5.75 km for the Patna Metro was calculated from the trip length ratios in the DPR and multiplied by the number of passengers transported.

Table 24-23 shows that Patna Metro is assumed to be considerably more efficient than Japanese subway operators with similar scale of operating kilometers, as it is assumed to transport 2 to 3 times as many passenger-kilometers as Japanese subway operators, and 4 to 5 times as many passengers per car as Japanese subway operators.

## Table 24-23: Transportation volume and facilities owned by subway operators

| Subway operator | Operating kilometer | Passenger Day kilometer | Volume of transported passengers | Transported Passenger kilometer | Passenger Train kilometer | Passenger Car kilometer | Passenger EMU kilometer | Total length of tracks | Total length of contact lines | Total length of feeder lines | Total length of power transmission lines | Total length of power distribution lines | Number of units of rolling stock | Number of stations | Oneman Operation kilometer |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | km | km | 1,000 persons | 1,000 Passenger kilometers | 1,000 kilometers | 1,000 kilometers | 1,000 kilometers | km | km | km | Km | km | Cars | Stations | km |
| Tokyo Metro | 195.0 | 71,398 | 2,765,003 | 22,285,546 | 35,685 | 292,574 | 292,574 | 411.5 | 572.3 | 278.9 | 312.9 | 1,824.6 | 2,716 | 179 | 71.0 |
| Sapporo | 48.0 | 17,569 | 226,909 | 1,346,938 | 5,748 | 33,707 | 33,707 | 96.0 | 116.4 | 64.7 | 53.0 | 115.4 | 368 | 49 | 48.0 |
| Sendai | 28.7 | 10,504 | 91,683 | 472,079 | 3,156 | 12,623 | 12,623 | 59.7 | 72.9 | 38.1 | 4.9 | 409.8 | 144 | 30 | 28.7 |
| Tokyo | 109.0 | 39,894 | 1,036,332 | 7,266,124 | 15,589 | 39,894 | 39,894 | 228.1 | 310.7 | 300.2 | 414.2 | 653.9 | 1,174 | 106 | 67.2 |
| Yokohama | 53.4 | 19,544 | 243,162 | 1,853,856 | 6,645 | 36,629 | 36,629 | 107.7 | 120.8 | 66.5 | 206.5 | 364.1 | 284 | 40 | 53.0 |
| Nagoya | 93.3 | 34,148 | 487,370 | 3,064,566 | 11,877 | 69,065 | 69,065 | 191.0 | 234.0 | 90.3 | 18.9 | 617.4 | 782 | 100 | 40.5 |
| Kyoto | 31.2 | 11,419 | 146,369 | 762,624 | 3,658 | 21,215 | 21,215 | 64.0 | 79.3 | 40.8 | 68.3 | 210.5 | 222 | 32 | 17.5 |
| Osaka | 129.9 | 47,543 | 902,637 | 5,408,129 | 17,489 | 114,048 | 114,048 | 266.0 | 323.5 | 467.6 | 165.2 | 1,151.8 | 1,284 | 123 | 39.5 |
| Kobe | 30.6 | 11,200 | 107,112 | 921,053 | 3,470 | 19,475 | 19,475 | 64.9 | 87.8 | 136.4 | 98.4 | 209.4 | 208 | 26 | 7.9 |
| Fukuoka | 29.8 | 10,907 | 173,294 | 903,555 | 3,557 | 18,746 | 18,746 | 64.7 | 129.3 | 88.9 | 65.4 | 212.4 | 212 | 36 | 29.8 |
| MM3 (2016) | 33.5 | 12,230 | 367,190 | 4,493,533 | 4,411 | 28,468 | 28,468 | 78.9 | 106.1 | 82.8 | 82.8 | 279.8 | 210 | 27 | 33.5 |
| Patna (2016) | 30.7 | 11,236 | 323,765 | 1,860,336 | 3,465 | 11,109 | 12,164 | 65.0 | 87.4 | 68.2 | 868.2 | 230.5 | 102 | 26 | 30.7 |

Source: Made by JST from the Annual Report of Railway Statistics and the Final Report on JICA Experts Study for the Operations and Maintenance Structure of Mumbai Metro Line 3 Project in India

b) Calculation of Yardstick standard unit cost

The Yardstick standard unit cost for subway operators (2020) specified by the Ministry of Land, Infrastructure, Transport and Tourism is calculated by the following regression equation.

- Cost of Tracks: Expenses for upkeep, maintenance, and work control for tracks and roadbeds;

  $y = 38{,}444.045\ x_1 - 191{,}352.136$

  Where
  - y: Yardstick unit cost per 1 km track length (1,000 yen)
  - $x_1$: Rolling stock density: natural logarithm of EMU-kilometer (1,000km)/total length of tracks (km)

- Cost of Electric Circuits: Expenses for upkeep, maintenance and work control of contact lines and signal equipment/facilities, etc.;

  $y = 10.452\ x_1 + 95.193\ x_2 - 1{,}379.091$

  Where
  - y: Yardstick unit cost per 1 km electric wire length (1,000 yen)
  - $x_1$: EMU density: EMU-kilometer (1,000 km)/ total length of contact lines (km)
  - $x_2$: Ratio of contact lines (%): Total length of contact lines (km)/total length of electric wires (km)

- Cost of Rolling Stock: Expenses for providing repair and maintenance services and work control for rolling stock;

  $y = 5.683\ x_1 + 3{,}150.717$

  Where
  - y: Yardstick unit cost per unit of rolling stock (1,000 yen)
  - $x_1$: Volume of transported passengers per unit of rolling stock Volume of transported passengers (1,000 persons)/number of units of rolling stock (cars)

- Cost of Train Operation: Expenses required for train operation and work control excluding power cost;

  $y = - 401.638\ x_1 + 157{,}524.047\ x_2 - 652{,}288.866$ (1,000 yen)

  Where
  - y: Yardstick unit cost per 1km electric wire length
  - $x_1$: Ratio of one-man operation (%): One-man operation-kilometer (km)/operating kilometers (km)
  - $x_2$: Train density: Natural logarithm of passenger train-kilometer (1,000 km)/operating kilometers (km)

- Cost of Station Duties: Expenses required for upkeep of stations and issuing tickets (1,000 yen);

  $y = 150{,}591.851\ x_1 - 1{,}099{,}458.024$

  Where

  y: Yardstick unit cost per station

  $x_1$: Volume of boarding passengers per station: Natural logarithm of volume of transported passengers (1,000 persons)/number of stations

Using the above regression equations, Table 24-24 through Table 24-28 show yardstick standard unit costs (cost of tracks, electric circuits, rolling stock, train operation, and station duties) for each subway calculated based on the operation volume and facility volume in 2020.

## Table 24-24: Yardstick Standard Unit Cost of Tracks (2020)

| Item | Patna | MM3 | Tokyo Metro | Sapporo | Sendai | Tokyo | Yokohama | Nagoya | Kyoto | Osaka | Kobe | Fukuoka |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total length of tracks (km) | 65.0 | 78.9 | 411.5 | 96.0 | 59.7 | 228.1 | 107.7 | 191.0 | 64.0 | 266.0 | 64.9 | 64.7 |
| EMU-kilometer (1,000km) | 11,109 | 26,468 | 292,574 | 33,707 | 12,623 | 39,894 | 36,629 | 69.065 | 21,215 | 114,048 | 19,475 | 18,746 |
| Rolling stock Density (EMU-kilometer/total length of tracks) | 170.88 | 335.46 | 710.99 | 351.12 | 211.44 | 174.90 | 340.10 | 361.60 | 331.48 | 428.75 | 300.08 | 289.74 |
| **Calculated unit cost (1,000 yen/km)** | **6,286** | **32,220** | **61,097** | **33,973** | **14,475** | **7,180** | **32,748** | **35,104** | **31,761** | **41,653** | **27,934** | **26,586** |

Source: Made by JST from MILT Annual Report of Railroad Statistics (FY2019) etc.

## Table 24-25: Yardstick Standard Unit Cost of Electric Circuits (2020)

| Item | Patna | MM3 | Tokyo Metro | Sapporo | Sendai | Tokyo | Yokohama | Nagoya | Kyoto | Osaka | Kobe | Fukuoka |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| EMU-kilometer (1,000km) | 11,109 | 26,468 | 292,574 | 33,707 | 12,623 | 39,894 | 38,629 | 69,065 | 21,215 | 114,048 | 19,475 | 18,746 |
| Total length of contact lines (km) | 87.4 | 106.1 | 572.3 | 116.4 | 72.9 | 310.7 | 120.8 | 234.0 | 79.3 | 323.5 | 87.8 | 129.3 |
| Total length of feeder lines (km) | 68.2 | 82.8 | 278.9 | 64.7 | 38.1 | 300.2 | 66.5 | 90.3 | 40.8 | 467.6 | 136.4 | 88.9 |
| Total length of power transmission lines (km) | 68.2 | 82.8 | 312.9 | 53.0 | 4.9 | 414.2 | 206.5 | 18.9 | 68.3 | 165.2 | 98.4 | 65.4 |
| Total length of power distribution lines (km) | 230.5 | 279.8 | 1,824.6 | 115.4 | 409.8 | 653.9 | 364.1 | 617.4 | 210.5 | 1,151.8 | 209.4 | 212.4 |
| Total length of all kind of electric lines (km) | 454.4 | 551.5 | 2,988.7 | 349.5 | 525.7 | 1,679.0 | 757.9 | 960.6 | 398.9 | 2,108.1 | 532.0 | 496.0 |
| EMU density | 127.07 | 249.46 | 511.23 | 289.58 | 173.16 | 128.40 | 303.22 | 295.15 | 267.53 | 352.54 | 221.81 | 144.98 |
| Ratio of contact Lines (%) | 19.24 | 19.24 | 19.15 | 33.31 | 13.87 | 18.51 | 15.93 | 24.36 | 19.88 | 15.35 | 16.50 | 26.07 |
| **Calculated yardstick unit cost (1,000 yen/electric wire kilometer)** | **1,780** | **3,060** | **5,787** | **4,818** | **1,751** | **1,725** | **3,307** | **4,025** | **3,310** | **3,768** | **2,510** | **2,618** |

Source: Made by JST from MILT Annual Report of Railroad Statistics (FY2019) etc.

## Table 24-26: Yardstick Standard Unit Cost of Rolling Stock (2020)

| Item | Patna | MM3 | Tokyo Metro | Sapporo | Sendai | Tokyo | Yokohama | Nagoya | Kyoto | Osaka | Kobe | Fukuoka |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volume of transported passengers (1,000 passengers) | 323,765 | 367,190 | 2,765,003 | 226,909 | 91,683 | 1,036,332 | 243,162 | 487,370 | 146,369 | 902,637 | 107,112 | 173,294 |
| Number of rolling stock | 102 | 210 | 2,716 | 368 | 144 | 1,174 | 284 | 782 | 222 | 1,284 | 208 | 212 |
| Number of transported passengers (1,000 persons/car) | 3,174,164 | 1,748,524 | 1,018,042 | 616,601 | 636,688 | 882,736 | 856,204 | 623,235 | 659,320 | 702,988 | 514,962 | 817,425 |
| **Calculated yardstick unit cost (1,000 yen/car)** | **21,189** | **13,088** | **8,936** | **6,655** | **6,769** | **8,167** | **8,017** | **6,693** | **6,898** | **7,146** | **6,077** | **7,796** |

Source: Made by JST from MILT Annual Report of Railroad Statistics (FY2019) etc.

## Table 24-27: Yardstick Standard Unit Cost of Train Operation (2020)

| Item | Patna | MM3 | Tokyo Metro | Sapporo | Sendai | Tokyo | Yokohama | Nagoya | Kyoto | Osaka | Kobe | Fukuoka |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| One-man operation-kilometer (km) | 30.7 | 33.5 | 71.0 | 48.0 | 28.7 | 67.2 | 53.0 | 40.5 | 17.5 | 39.5 | 7.9 | 29.8 |
| Operating kilometer | 30.7 | 33.5 | 195.0 | 48.0 | 28.7 | 109.0 | 53.4 | 93.3 | 31.2 | 129.9 | 30.6 | 29.8 |
| Passenger train-kilometer (1,000 km) | 3,465 | 4,411 | 35,685 | 5,748 | 3,156 | 15,589 | 6,645 | 11,877 | 3,658 | 17,489 | 3,470 | 3,557 |
| One-man operation km ratio (%) | 100.0 | 100.0 | 36.4 | 100.0 | 100.0 | 61.7 | 99.3 | 43.4 | 56.1 | 30.4 | 25.8 | 100.0 |
| Train density (logarithm) | 4.73 | 4.88 | 5.21 | 4.79 | 4.70 | 4.96 | 4.82 | 4.85 | 4.76 | 4.90 | 4.73 | 4.78 |
| **Calculated yardstick unit cost (1,000 yen/ operating kilometer)** | **52,038** | **76,314** | **153,707** | **61,364** | **47,936** | **104,737** | **67,714** | **93,723** | **75,668** | **107,770** | **82,574** | **60,853** |

Source: Made by JST from MILT Annual Report of Railroad Statistics (FY2019) etc.

## Table 24-28: Yardstick Standard Unit Cost of Station Duties (2020)

| Item | Patna | MM3 | Tokyo Metro | Sapporo | Sendai | Tokyo | Yokohama | Nagoya | Kyoto | Osaka | Kobe | Fukuoka |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Volume of transported Passengers (1,000 persons) | 323,765 | 367,190 | 2,765,003 | 226,909 | 91,683 | 1,036,332 | 243,162 | 487,370 | 146,369 | 902,637 | 107,112 | 173,294 |
| Number of Stations | 26 | 27 | 179 | 49 | 30 | 106 | 40 | 100 | 32 | 123 | 26 | 36 |
| Logarithms (ln) of volume boarding passengers (1,000 persons/ station) | 9.43 | 9.52 | 9.65 | 8.44 | 8.03 | 9.19 | 8.71 | 8.49 | 8.43 | 8.90 | 8.32 | 8.48 |
| Calculated yardstick unit cost (1,000 yen/station) | 320,574 | 333,845 | 353,025 | 171,610 | 109,026 | 284,144 | 212,589 | 179,309 | 169,753 | 240,944 | 153,998 | 177,444 |

Source: Made by JST from MILT Annual Report of Railroad Statistics (FY2019) etc.

c) Total of the Yardstick standard costs

Table 24-29 shows the total Yardstick standard costs obtained from the quantity of equipment/facilities and yardstick unit costs.

## Table 24-29: Total Yardstick standard costs (2020)

| Item | Patna | MM3 | Tokyo Metro | Sapporo | Sendai | Tokyo | Yoko hama | Nagoya | Kyoto | Osaka | Kobe | Fukuoka |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Quantity of Equipment/Facilities** | | | | | | | | | | | | |
| Total length of tracks (km) | 65.0 | 78.9 | 411.5 | 96.0 | 59.7 | 228.1 | 107.7 | 191.0 | 64.0 | 266.0 | 64.9 | 64.7 |
| Total length of electric wires (km) | 454.4 | 551.5 | 2,988.7 | 349.5 | 525.7 | 1,679.0 | 757.9 | 960.6 | 398.9 | 2,108.1 | 532.0 | 496.0 |
| Number of units of rolling stock (car) | 102 | 210 | 2,716 | 368 | 144 | 1,174 | 284 | 782 | 222 | 1,284 | 208 | 212 |
| Operating kilometer (km) | 30.7 | 33.5 | 195.0 | 48.0 | 28.7 | 109.0 | 53.4 | 93.3 | 31.2 | 129.9 | 30.6 | 29.8 |
| No. of stations | 26 | 27 | 179 | 49 | 30 | 106 | 40 | 100 | 32 | 123 | 26 | 36 |
| **Yardstick unit cost (1,000 yen)** | | | | | | | | | | | | |
| Cost of tracks per kilometer | 6,286 | 32,220 | 61,097 | 33,973 | 14,475 | 7,180 | 32,748 | 35,104 | 31,761 | 41,653 | 27,934 | 26,586 |
| Cost of electric circuits per kilometer | 1,780 | 3,060 | 5,787 | 4,818 | 1,751 | 1,725 | 3,307 | 4,025 | 3,310 | 3,766 | 2,510 | 2,618 |
| Cost of rolling stock per car | 21,189 | 13,088 | 8,936 | 6,655 | 6,769 | 8,167 | 8,017 | 6,693 | 6,898 | 7,q46 | 6.077 | 7,796 |
| Cost of train operation per system kilometer | 52,038 | 76,314 | 153,707 | 61,364 | 47,936 | 104,737 | 67,714 | 93,723 | 75,668 | 107,770 | 82,574 | 60,853 |
| Cost of station duties per station | 320,574 | 333,845 | 353,025 | 171,610 | 109,026 | 284,144 | 212,589 | 179,309 | 169,753 | 240,944 | 153,998 | 177,444 |
| **Calculated unit cost (million yen)** | | | | | | | | | | | | |
| Cost of tracks | 409 | 2,542 | 25,141 | 3,261 | 864 | 1,638 | 3,527 | 6,705 | 2,033 | 11,080 | 1,813 | 1,720 |
| Cost of electric circuits | 809 | 1,687 | 17,296 | 1,684 | 920 | 2,895 | 2,507 | 3,866 | 1,320 | 7,940 | 1,335 | 1,298 |
| Cost of rolling stock | 2,161 | 2,748 | 24,271 | 2,449 | 975 | 9,588 | 2,277 | 5,234 | 1,531 | 9,175 | 1,264 | 1,653 |
| Cost of train operation | 1,598 | 2,557 | 29,973 | 2,945 | 1,376 | 11,416 | 3,616 | 8,744 | 2,361 | 13,999 | 2,527 | 1,813 |
| Cost of station duties | 8,335 | 9,014 | 63,192 | 8,409 | 3,271 | 30,119 | 8,504 | 17,931 | 5,432 | 29,636 | 4,004 | 6,388 |
| **TOTAL** | | | | | | | | | | | | |
| **Actual amount** | **13,312** | **18,548** | **159,872** | **18,749** | **7,406** | **55,657** | **20,430** | **42,480** | **12,677** | **71,830** | **10,943** | **12,873** |

Source: Made by JST from MILT Annual Report of Railroad Statistics (FY2019) etc.

### 3) Estimated expenses at PMRCL based on Japan-India comparison

#### a) Ratio of labor cost in Japan

Personnel costs and expenses by sector for Japanese railway operators are listed in the income and expenditure tables of the Annual Report of Railway Statistics, and Table 24-30 summarizes the subway operator's portion of these costs. The average labor cost percentages for each sector tend to be large for train operation and station service expenses, and small for track and rolling stock expenses.

**Table 24-30: Personnel costs and expenses of Japanese subway operators (2020)**

| Item | Tokyo Metro | Sapporo | Sendai | Tokyo | Yokohama | Nagoya | Kyoto | Osaka | Kobe | Fukuoka | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Cost of tracks (million yen)** | | | | | | | | | | | |
| Personnel cost | 3,482 | 187 | 432 | 3,538 | 885 | 3,056 | 312 | 2,361 | 485 | 341 | |
| Expenses | 20,656 | 2,365 | 1,471 | 10,181 | 1,904 | 4,693 | 1,376 | 5,033 | 556 | 1,895 | |
| Ratio of personnel cost | 14% | 7% | 23% | 26% | 32% | 39% | 18% | 32% | 47% | 15% | **25%** |
| **Cost of electric circuits (million yen)** | | | | | | | | | | | |
| Personnel cost | 6,006 | 162 | 411 | 4,072 | 776 | 2,002 | 573 | 3,266 | 627 | 353 | |
| Expenses | 10,802 | 1,478 | 1,178 | 4,406 | 592 | 1,236 | 890 | 2,965 | 468 | 1,516 | |
| Ratio of personnel cost | 36% | 10% | 26% | 48% | 57% | 62% | 39% | 53% | 57% | 19% | **41%** |
| **Cost of rolling stock (million yen)** | | | | | | | | | | | |
| Personnel cost | 8,650 | 499 | 286 | 3,253 | 447 | 2,961 | 673 | 4,175 | 503 | 319 | |
| Expenses | 9,178 | 1,702 | 772 | 6,478 | 1,799 | 1,745 | 782 | 1,689 | 371 | 1,708 | |
| Ratio of personnel cost | 49% | 23% | 27% | 35% | 20% | 63% | 46% | 71% | 58% | 16% | **41%** |
| **Cost of train operation (million yen)** | | | | | | | | | | | |
| Personnel cost | 29,526 | 2,672 | 1,034 | 11,033 | 2,764 | 8,518 | 1,909 | 10,102 | 2,402 | 1,363 | |
| Expenses | 8,999 | 1,296 | 526 | 4,611 | 1,194 | 3,567 | 651 | 4,109 | 681 | 956 | |
| Ratio of personnel cost | 77% | 67% | 66% | 71% | 70% | 70% | 75% | 71% | 78% | 59% | **70%** |
| **Cost of station duties (million yen)** | | | | | | | | | | | |
| Personnel cost | 30,529 | 177 | 1,149 | 11,349 | 2,748 | 7,813 | 1,522 | 16,174 | 1,327 | 1,458 | |
| Expenses | 23,055 | 4,653 | 1,643 | 16,417 | 2,404 | 6,068 | 2,233 | 8,099 | 1,787 | 1,879 | |
| Ratio of personnel cost | 57% | 57% | 4% | 41% | 53% | 56% | 41% | 67% | 43% | 44% | **45%** |

Source: Made by JST from MILT Annual Report of Railroad Statistics (FY2019) etc.

b) Assumption of O&M cost if PMRCL exists in Japan

Next, we assume the O&M costs if Patna Metro were to exist in Japan. Table 24-31 shows the division of PMRCL's departmental base costs determined in Table 24-29 into labor and expenses, using the average labor cost ratio shown in Table 24-30.

**Table 24-31: Assumed O&M costs if Patna Metro were to exist in Japan**

| Item | O&M expenses | Ratio of personnel expenses | Personnel expenses | Other expenses | TOTAL |
|---|---|---|---|---|---|
| | Million yen/year | % | Rs. in Crore | Rs. in Crore | Rs. in Crore |
| Track costs | 409 | 25 | 7.19 | 21.16 | 28.35 |
| Electric line costs | 809 | 41 | 22.78 | 33.34 | 56.12 |
| Rolling Stock costs | 2,161 | 41 | 61.01 | 88.90 | 149.92 |
| Train operating costs | 1,598 | 70 | 77.89 | 32.92 | 110.81 |
| Station expenses costs | 8,335 | 45 | 257.67 | 320.46 | 578.13 |
| **TOTAL** | **13,312** | | **426.54** | **496.79** | **923.33** |

Remark 1: Expenses include power costs
Remark 2:1Rs=1.4417yen (Average exchange rate in 2020)

Source: JST

4) Reasonableness of O&M costs as stated in the DPR

In DPR, O&M costs are calculated by dividing them into personnel, maintenance, and power costs.

For labor costs, DPR assumes a total of 1,124 personnel, assuming 35 personnel/km for a total route length of 32.1 km, multiplied by the average wage of 0.078 Rs. in crore in 2018, and taking into account a 9% annual increase in labor costs, the total personnel cost is estimated to be 146.5 Rs. in Crore in the opening year 2024.

For maintenance costs, the maintenance cost per kilometer as of 2018 is assumed to be 1.74 Rs. in Crore/km, and taking into account a 5% annual increase in material costs, it is estimated to be 74.9 Rs. in Crore in 2024, at the time of opening.

Power costs are assumed to be 100 Rs. in Crore in 2024.

The total O&M cost in 2024, the year of opening, as stated in the DPR, is 321.4 Rs. in Crore, which is only about 1/3 of the total labor cost and expenses shown in Table 24-31, which was calculated using the yardstick method. Although this price difference can be considered large, it is not an uncomfortable difference since the price difference is expected to disappear and reach the same level as Japan around 2037 if India's rapid growth and rising prices continue in the future. In addition, the ratios of labor and property costs in the DPR are almost equal, which is the same as in Japan.

Based on the above, it is safe to assume that the O&M expenses stated in the DPR are generally appropriate.

Table 24-32 shows the O&M costs by year in PMRCL revised to take into account the changes from the DPR in the operation plan.

**Table 24-32: Revised Operation and Maintenance Costs (Rs. In Crore)**

| Year | Staff Cost | Maintenance Expenses | Energy Charges | Total O&M Cost | Addition/Replacement cost |
|---|---|---|---|---|---|
| Esc | @9% | @5% | @5% (*1) | | |
| 2024 | 142 | 72 | 97 | 310 | |
| 2025 | 154 | 76 | 101 | 332 | |
| 2026 | 168 | 80 | 106 | 354 | |
| 2027 | 183 | 84 | 112 | 379 | |
| 2028 | 200 | 88 | 117 | 405 | |
| 2029 | 218 | 92 | 123 | 433 | |
| 2030 | 237 | 97 | 129 | 464 | |
| 2031 | 259 | 125 | 175 | 558 | 559 (Addition of 54 coaches) |
| 2032 | 282 | 131 | 184 | 596 | |
| 2033 | 307 | 137 | 193 | 638 | |
| 2034 | 335 | 144 | 202 | 682 | |
| 2035 | 365 | 151 | 212 | 729 | |
| 2036 | 398 | 159 | 223 | 780 | |
| 2037 | 434 | 167 | 234 | 835 | |
| 2038 | 473 | 175 | 246 | 894 | |
| 2039 | 516 | 184 | 258 | 958 | |
| 2040 | 562 | 193 | 271 | 1,027 | |
| 2041 | 613 | 207 | 306 | 1,126 | 151 (Addition of 12 coaches) |
| 2042 | 668 | 217 | 322 | 1,207 | |
| 2043 | 728 | 228 | 338 | 1,294 | |
| 2044 | 793 | 240 | 355 | 1,388 | 2,585 (Replacement of 25% of Elec & 50% S&T assets) |
| 2045 | 865 | 252 | 373 | 1,489 | |
| 2046 | 943 | 264 | 391 | 1,598 | |
| 2047 | 1,028 | 277 | 411 | 1,716 | |
| 2048 | 1,120 | 291 | 431 | 1,842 | |
| 2049 | 1,221 | 306 | 453 | 1,979 | |
| 2050 | 1,331 | 321 | 475 | 2,127 | |
| 2051 | 1,450 | 361 | 551 | 2,363 | 369 (Addition of 24 coaches) |
| 2052 | 1,581 | 379 | 579 | 2,539 | |
| 2053 | 1,723 | 398 | 608 | 2,729 | |

*1: Escalation of 5% per annum is applied on power tariff. Traction Power is increasing in every Horizon year with increase in no. of trains in horizon year. And Non -Traction power is increasing with 10 % escalation in every horizon years.

Source: DPR

# 25. Comments and Suggestions on DPR

This chapter describes DPR evaluation and summarizes suggestion for improvement which are reported in the previous chapters. The overall evaluation, insufficient items and improvement suggestions relating to DPR, proposed by JST during this survey, are shown in the table below by each fields.

**Table 25-1: Comments and Suggestions on DPR**

| Field | Comments |
|---|---|
| Travel Characteristics and Demand Estimates | **Overall:**<br>DPR provides the description of the demand projection approach and the projection result, however, the quality of the model is not good. Provision of the model from Indian side was not smooth.<br>**Insufficient items:**<br>• There was no reproducibility in the model. The model result was not same to DPR result.<br>• The modal share of public transport is set by the modeler, rather than the simulation result of the models, which is not consistent with the analysis approach described in DPR. Moreover, the model cannot assess the competition among public/private transport modes which is key factor of F/S. 3) JST took a few months to obtain from Indian side.<br>**Improvement proposals suggested by JST:**<br>The revision includes the change of MRT opening year (to 2028 as per the latest implementation schedule), as well as the revision of public transport share considering Patna's characteristics and the situation in similar India cities, which suggested the DPR setting of modal share on public transport (70%) was too high, therefore JST suggested modest setting. A staged growth of MRT demand was proposed, and the demand projection is finalized accordingly. |
| Route Plan and Alignment | **Overall:**<br>The DPR covers all necessary studies, and although there are minor deviations from the standards, they do not greatly affect the basic alignment plan.The accuracy of the studies generally satisfies the standards.<br>**Insufficient items:**<br>Although necessary studies are covered, the following two information required to check alignment are not described.<br>• Calculation formula of cant<br>• Types of transition curves<br>Even if it is general, it is necessary to ensure that it is clearly stated.<br>**Improvement proposals suggested by JST:**<br>The Main Track alignment is the one that was proposed at the Improvement Proposal Meeting.<br>It was confirmed that the alignment of the Main Track had been corrected after the improvement proposal meeting, so there is nothing to be improved.<br>The DEPOT adopted the proposal to change the layout of turnouts and improve access from the Main Workshop to the Test Track. |
| Track | **Overall:**<br>The track structures are decided based on Procedure for Safety Certification and Technical Clearance of Metro Systems issued by Research Designs & Standards Organization (RDSO), which is a standard specification in India used in precedent Metro Projects as well.Therefore, it can be said that the plan is reasonable.<br>**Insufficient items:**<br>It is not mandatory, though the below is recommended to be improved.<br>• Comparison of precast Plinth track and cast-in-situ Plinth track<br>• Mitigation major for noise and vibration<br>• Use of rail based on requirements of the depot<br>• Rail welding testing based on types of rail welding<br>**Improvement proposals suggested by JST:**<br>• Carrying out a comparison of precast Plinth track and cast-in-situ Plinth track in advance<br>• Carrying out consideration of Mitigation major for noise and vibration<br>• Using the smaller-cross section rail in the depot |

| Field | Comments |
|---|---|
| | • Using the magnetic particle testing for flash butt welding |
| Engineering Survey | **Overall:**<br>The engineering survey items in the DPR were adequate and the accuracy of survey results were also satisfactory as DPR.<br>However, as a redult of focusing on checking the geotechnical survey report prepared by the geotechnical sub-consultant, it seems that the geotechnical engineer's review and assessment were insufficient at the DPR phase.<br>**Insufficient items:**<br>There was a lack of the review and assessment by geotechnical engineers during the DPR phase.<br>**Improvement proposals suggested by JST:**<br>Reconfirmation of the laboratory test results (O.C.R.) values of geotechnical survey. |
| Civil Engineering | **Overall:**<br>The items in DPR were adequateand and the contents were also safisfactory as DPR This study conducted review of the basic design stage, this basic design stage is the next steps in the DPR.<br>**Insufficient items:**<br>The basic design drawing of underground station was mainly the architectural planning.PMRCL/DMRC was requested to provide additional basic design on the civil engineering aspects, but the PMRCL/DMRC replied that it was a design-build construction contract and the Contractor should carry out the detailed design. However, some improvement request by JST were accepted by PMRCL/DMRC.<br>**Improvement proposals suggested by JST:**<br>• TBM construction sequence at Patna Junction Station<br>• Monitoring zone at TBM crossing point with Indian National Railway<br>• Consideration point of the Design and Construction for Depot Civil<br>• Countermeasure of rainwater flooding under climate change |
| Station Planning | **Overall:**<br>The DPR is covered necessary study and consideration items. It is described the layout plan for station facilities, station layout plan, conceptual design, Building laws and regulations, design criteria for station building. In addition, it was confirmed that consideration of Barrier free and Gender measures in the DPR.<br>**Insufficient items:**<br>The DPR is not include a study on connections/transfers between the station building and the main public transport facilities around the station. It is recommended that the DPR is described the connection plan, as a connection/transfer study is required in the planning of Entry and Exit and the concourse layout.<br>• Study on the transfer plan with the National Railways stations at Patna and Rajendra Nagar stations.<br>• Study on the connection and convenience of the New bus terminal at New ISBT station.<br>**Improvement proposals suggested by JST:**<br>• The PSD is not installed at the new construction due to passenger demand forecasts and cost considerations. But if it becomes necessary to install PSD due to safety measures in the future, it is recommended that post installation type PSD are installed that are suitable for the current planned platform structure.<br>• The platform width in the Corridor-2 drawing should be revised matching with new coach width due to the coach width is changed from 3,200 mm to 2,900 mm. |
| Inter-Modal Integration | **Overall:**<br>The DPR proposes comprehensive idea for the inter-modal integration facility with focusing the main 6 stations. Such "Salt & Spice" proposals for focused on major stations will enhance the implementation. The whole proposals are comprehensive including soft and hard counter measures.<br>**Insufficient items:**<br>The implementation cost, institutional settings, tariff setting for the feeder bus services are unclear. Competition with the existing route buses under BMRTC is also risk. The proposals are comprehensive, however, it depends on the budget of the PMRCL, and it is unclear that how passenger demand will be influenced by the shortage of the budget and less services for intermodal integrations.<br>**Improvement proposals suggested by JST:**<br>The feeder bus implementation will need sufficient lead time, as mentioned in the Roadmap in the Chapter 7. Negotiation with the Transport Bureau of the Bihar for feeder bus service installation should be started as proposed. |

| Field | Comments |
|---|---|
| Train Operation Plan | **Overall:**<br>Corridor 1 and 2 had operation plans according to each year's PHPDT, but it included the following issues.<br>**Insufficient items:**<br>• Adverse effects of mixed 3- and 6-car trains on corridor 1 (passenger imbalance, absence of spare trains, impossibility of rescue operations, etc.)<br>• Adverse effects of bad alignment at KhemniChak station (interference between corridor 1 trains not in service to/from depot and corridor 2 commercial trains)<br>• Whether or not there is an impact due to reduction of car width from 3.2m in DPR to 2.9m.<br>**Improvement proposals suggested by JST:**<br>Suggestion for improvement to the above problems. However, regarding the alignment, the construction of KhemniChak station has already started, so it is the next opinion. |
| Signaling and Telecommunication | **Overall:**<br>Design policies for Signalling and Telecommunication were identified through your DPR and interviews. However, it was not easy to understand the design policies from your DPR alone.<br>**Insufficient items:**<br>JST recommends the following items be incorporated into the DPR.<br>• Overall system configuration diagram between OCC/BCC and station/depot<br>• The primary technical specification tables for the major systems/devices/equipment<br>• The authorization process when a contractor uses standards different from your requirements<br>**Improvement proposals suggested by JST:**<br>• JST recommends that PMRCL introduces the systems/devices/equipment or specification within the scope of the current plan.<br>• JST recommends that PMRCL ensures the CBTC radio bands for Corridor 1 and 2 don't interfere at the detailed design stage. |
| Fare Collection System | **Overall:**<br>Design policies for Signalling and Telecommunication were identified through your DPR and interviews. However, it was not easy to understand the design policies from the DPR alone.<br>**Insufficient items:**<br>JST recommends the following items be incorporated into the DPR.<br>• Overall system configuration diagram.<br>• The primary technical specification tables for the major systems/devices/equipment<br>**Improvement proposals suggested by JST:**<br>• JST recommends that PMRCL introduces the systems/devices/equipment or specification within the scope of the current plan.<br>• JST recommends PMRCL to use UPSs for facilities that could directly affect the train operation and UPSs for facilities that could not directly affect the train operation separately, with the perspective of stable train operation. |
| Rolling Stock | **Overall:**<br>The Specifications were baased on Delhi Metro Corridor 7 and 8.<br>**Insufficient items:**<br>Equipment cooling method and measures to convert 3-car trains to 6-car trains were not discussed properly in DPR.<br>**Improvement proposals suggested by JST:**<br>JST proposed suggestion for improvement to the above problems. |
| Power Supply and Traction | **Overall:**<br>In the DPR, traction system and many of the facilities were similar to those used in the Delhi Metro, which has a proven track record in many areas. On the other hand, energy-saving measures were taken, such as the use of LED for lighting and VRV for air-conditioning, which resulted in lower power consumption and more compact transformers than on many lines.<br>**Insufficient items:**<br>India has not obtained information on actual short-circuit capacity because it has adopted the regulation value for the short-circuit capacity at the receiving point, regardless of the city. Since the short-circuit capacity tends to be smaller in rural city such as Patna than in metropolitan city such as Delhi, it is recommended that the short-circuit capacity be considered in the DPR. |

| Field | Comments |
|---|---|
| | **Improvement proposals suggested by JST:**<br>Since Patna Metro is expected to have a small short-circuit capacity and the number of substations is small, there were concerns that the use of single phase transformer would cause voltage unbalance, so we proposed to use the scott connected transformer |
| Depots | **Overall:**<br>It has almost sufficient facilities and capacity.<br>**Insufficient items:**<br>Moving route from the workshop to the test track was not studied properly in DPR.<br>**Improvement proposals suggested by JST:**<br>JST proposed suggestion for improvement to the above problems. |
| Environmental Impact Assessment | **Overall:**<br>Compared to the JICA guidelines, some deficiencies were found in the environmental impact assessment items, mitigation measures, and environmental monitoring plan by PMRCL. But overall, the assessment and plan covered the major impacts assumed by the project, which is considered satisfactory. Since there were still deficiencies in the item of Protected areas, Ecosystems, and monitoring frequency, JST suggested the following improvements.<br>**Insufficient items:**<br>Since the project was located in an urban area, there was insufficient consideration for the rare green zone and ecosystems that remain there. JST proposed that mitigation measures and monitoring plans be developed and implemented for the fauna and flora that inhabit the Danapur Cantonment KBA and SGB Park (Patna Zoo). JST also proposed that monitoring frequency for air quality, water quality, noise and vibration be conducted monthly during construction and biannually during operation.<br>**Improvement proposals suggested by JST:**<br>• Site inspection focusing on nesting and flying in KBA.<br>• Implementation of noise/vibration mitigation measures for construction around Patna Zoo station.<br>• Monitoring frequency: Basically, monthly during construction and biannually during operation (with some excepted items) |
| Social Impact Assessment | **Overall:**<br>Considering that the Project is in DFR Phase, and the society is under influence of COVID, the report was developed with acceptable designs and records of surveys of affected areas, measures of minimization of impacts, identification of affected households, census survey, identification of socially vulnerable groups, and implementation of public consultation meetings.<br>**Insufficient items:**<br>The following improvements were found necessary in the DPR.<br>• Correction was needed to eliminate the Partially Affected Households (No need for resettlement) from the entitlement for the Resettlement Allowance.<br>• Record of public consultation must have been clear about the names of person (both question and answer) with summary of comments.<br>• Negotiation and coordination was needed to come to same understandings between PMRCL and JICA/JST, about the entitlement and evacuation timing of the squatters and commercial encroachers on public lands.<br>**Improvement proposals suggested by JST:**<br>JST made 3 improvements mentioned above.<br>JST implemented additional study and consultation with PMRCL about the relocation and rehabilitation assistances for the squatters and encroachers on public land.<br>JST proposed gender integration plan and monitoring in PMRCL, and customer satisfaction survey. |
| Detailed Project Cost Estimates | **Overall:**<br>Major items are covered in the DPR cost estimates and quantities/unit prices are calculated properly<br>**Insufficient items:**<br>The following items should have been considered in the DPR.<br>• Estimates for respective contract packages<br>• Price escalation was not taken into account properly.<br>• Project implementation schedule was incorporated in the estimate.<br>• LC/FC ratio was not assumed.<br>• Consultant fee was not estimated with breakdown<br>**Improvement proposals suggested by JST:**<br>JST estimated the items mentioned above. |

| Field | Comments |
|---|---|
| Transit Oriented Development Plan | **Overall:**<br>• In Japan, TOD includes station development, real estate development, and urban development. However, DPR categorizes LVC (Land Value Capture) as TOD revenue, and station development and real estate development as non-fare box revenue.<br>• DPR plans to allocate 35% of the LVC to PMRCL, but the details of the scheme, etc., are yet to be considered.<br>**Insufficient items:**<br>• Patna City is in charge of planning the scheme of LVC. It is required to consider a specific scheme and revenue estimate.<br>**Improvement proposals suggested by JST:**<br>JST proposed the technical assistances and consulting as follows.<br>• Capacity development for TOD (transit oriented development for city planning along metro corridors)<br>Redevelopment of the station square of Patna Junction Station, which is connecting to Indian Railways |
| Digital Transformation (DX) | **Overall:**<br>JST proposed the Felica-type IC cards. However PMRCL planned to introduce the National Common Card (NCMC) promoted by the Government of India.<br>**Insufficient items:**<br>In order for Patna Metro to be the hub of public transportation in the city, it is important to promote the use of transportation by introducing DX and MaaS. DX and Maas regarding services will be considered from now on.<br>**Improvement proposals suggested by JST:**<br>JST proposed the business trials as follows.<br>• Installation of EV charging facilities at metro stations and business trial for commercialization of selling solar power electricity<br>• Business trial for on-demand mobility business |
| Non Fare Box Revenue | **Overall:**<br>The non-fare box business which PMRCL is considering are common among other metro companies in India. In addition, the revenue estimates is reasonable. Because the estimates is considering the average income or economic growth rate of the states, and calculated using Chennai Metro and Jaipur Metro as benchmarks.<br>**Insufficient items:**<br>Three real estate developments along the corridors are being considered. However, a specific development plan has yet to be determined.<br>**Improvement proposals suggested by JST:**<br>JST proposed the technical assistances and consulting as follows.<br>• Capacity development for non-fare box business (retails/advertisement in station area etc.)<br>• Capacity development for non-fare box business (property development business) |
| Financial Analysis | **Overall:**<br>• The calculation criterias were similar to those used by other DPRs, and no particular problems were found.<br>• The comparison of the funding schemes was clearly analyzed, and the person in charge comprehensively responded to inquiries from the JST.<br>• There was no clear explanation for the decision to adopt the PPP scheme for the AFC procurement, instead of including in the loan portion. On the other hand, JST understands that it was inevitable in the context of the MoHUA guidelines, which recommend the introduction of PPP schemes, even partially, in metro projects in India.<br>**Insufficient items:**<br>• The fare revision was set at a 7.5% increase every two years, but this was not realistic from the view of the time required for the actual fare revision.<br>**Improvement proposals suggested by JST:**<br>• Concerning the fare revision, the frequency was changed to once every five years. |

| Field | Comments |
|---|---|
| Economic Analysis | **Overall:**<br>• The MoHUA guidelines set the EIRR of 14% or more as a threshold, so it is unavoidable to achieve this for the metro construction. However, there were some calculating methods of benefits that made it difficult to understand the background.<br>• Although the reduction of the Vehicle Operating Costs (VOC) includes the cost deprecistion, the reduction of initial investment costs of vehicles and the reduction of the VOC along the corridors were included in the calculation.<br>**Insufficient items:**<br>• The clarification of the calculating method of economic benefits are necessary.<br>**Improvement proposals suggested by JST:**<br>• Economic benefits considered duplicative were excluded from the calculations, such as the initial vehicle procurement costs and reduction in the cost of running vehicles owned by residents along the route. |
| Implementation Plan | **Overall:**<br>The contents in DPR are the different level from this study scope. That is, DPR mainly refers to the way of establishing the implementation agency and roles of concerned government departments, which should be decided before the JICA preparatory study begins.<br>**Insufficient items:**<br>As DPR was revised in January 2021, the section can be requested to contain the latest information on engaging entities at that time such as DMRC and procured packages/contractors.<br>The implementation schedule is quite optimistic and simply demonstrated. That tells the train operation starts four years after DPR revision is completed.<br>**Improvement proposals suggested by JST:**<br>Proposed a realistic project implementation schedule.<br>Proposed an implementing organization by considering DMRC engagement.<br>As per the JICA study scope, proposed the procurement plan and reviewed the safety management plan, which are not included in DPR. |
| Operation and Maintenance (O&M) | **Overall:**<br>The number of personnel and costs required for the O&M phase were calculated. They were generally appropriate.<br>**Insufficient items:**<br>The following considerations were lacking.<br>• Specific organizational structure for O&M and number of personnel required for each department<br>• Hire and train plan for O&M personnel<br>• Number and timing of hiring of drivers who need time for training.<br>• Specific training content and means, such as equipment, required for training<br>**Improvement proposals suggested by JST:**<br>• Re-estimate the number of personnel and costs based on proposals for improvement of the transportation plan<br>• JST estimated the items mentioned above. |

Source: JST

# 26. Utilization of Japanese Technologies

## 26.1 List of Japanese companies associated with metro projects in India

The table below shows the list of Japanese companies associated with metro projects in India

**Table 26-1: Japanese companies associated with metro projects in India**

| No. | Company | Field |
|---|---|---|
| **Delhi Matro** | | |
| **Phase 1** | | |
| 1 | Kumagai Gumi Co.,Ltd. & Itochu Corporation | Civil |
| 2 | Kumagai Gumi Co.,Ltd. & Itochu Corporation | Civil |
| 3 | Shimizu Corporation | Civil |
| 4 | Mitsubishi Corporation, Mitsubishi Electric Corporation | Rolling Stock |
| 5 | Sumitomo Corporation | Signal &Telecommunication |
| 6 | Mitsubishi Corporation, Mitsubishi Electric Corporation | Rolling Stock |
| 7 | Sumitomo Corporation | Signal &Telecommunication |
| 8 | Nippon Steel Corporation, Mitsui & Co.,Ltd. | Track |
| 9 | Nippon Signal Co.,Ltd. | Signal (Automatic Train Operation) |
| **Phase 2** | | |
| 1 | Shimizu Corporation | Civil |
| 2 | Nippon Signal Co.,Ltd. | Signal (Automatic Train Operation) |
| **Phase 3** | | |
| 1 | Nippon Signal Co.,Ltd. | Signal (Automatic Train Operation) |
| **Bangalore Metro** | | |
| Phase 1 | | |
| 1 | Alstorm Transport SA-Thales Group Portugal-Sumitomo Corporation | Signalling & Telecomunications Systems |
| 2 | Hitashi Zosen Corporation | TBM Machine |
| Phase 2 | | |
| 1 | Mitsui & Co.,Ltd. | Track |
| **Chennai Metro** | | |
| Phase 1 | | |
| 1 | Nippon Signal Co.,Ltd. | AFC System |
| Phase 2 | | |
| 1 | Mitsui & Co.,Ltd. & Ohmi Industries,Ltd. | Track |
| **Ahmedabad Metro** | | |
| Phase 1 | | |
| 1 | Nippon Signal Co.,Ltd. | Signalling and Train Control Systems & AFC |
| 2 | Mitsui & Co.,Ltd. | Track |
| **Mumbai Metro** | | |
| 1 | Mitsui & Co.,Ltd. | Track |

Source: JST

## 26.2 Proposal

### 26.2.1 Track

#### (1) HH Rail

DPR proposes to use HH rails for the main line. There is one steel Indian company, Jindal Steel and Power, and some non-Indian companies, Mitsui, JFE steel, ArcelorMittal, Voestalpine and Evraz, are capable of delivering HH rails to India. Japanese steel companies have some delivery records, including Western Dedicated Freight Corridor, Bangalore Metro and Mumbai Metro etc. in the Indian rail market, which can lead Japanese companies to be still competitive.

#### (2) Composite sleeper

PSTM says that pre-stressed concrete sleepers or mono-block sleepers are used for turnouts in Indian Metro, but lack of flexibility in the construction and installation process is one of the drawbacks of theses sleepers. On the other hand, composite sleepers are used primarily for special sections including, stations, bridges, turnouts and expansion joints in Japan. It is made of a continuous glass fiber-reinforced polyurethane foam. The shape of the composite sleeper is similar to that of ordinary wooden sleepers. The construction and installation process is simple, and the composite sleepers can be sawed, planed, nailed, screwed and glued with standard woodworking tools. So, it makes the installation process easier and faster. And it ensures long durability. So, JICA survey team would like to propose using composite sleepers in Patna Metro, as well.

Composite sleepers are manufactured by some companies, including Japanese makers, Sekisui Chemical and Sumihatsu. They have the intention to expand their market to India. They have some delivery records in Asia and European countries, proving they have good competitiveness with other makers.

PMRCL states the intention not to use a composite sleeper in the talks during JICA survey.



Source: SEKISUI FFU Synthetic Sleeper brochure site: https://www.sekisui-rail.com/en/brochures-ffu-synthetic-wood.html

**Figure 26-1: Use of Composite sleepers**

### 26.2.2 Signaling and Telecommunication

#### (1) Signaling

- JST has confirmed some Indian suppliers can manufacture Signaling devices/equipment, such as the Electric Point Machine. However, JST has also confirmed no Indian supplier can manufacture CBTC, including ATP.

- JST has confirmed that some Japanese suppliers can manufacture CBTC and have recently experienced Indian metro projects such as Delhi, Mumbai, Kolkata, Ahmedabad, etc.
- Therefore, JST has confirmed that CBTCs manufactured by Japanese suppliers have no concerns about Conformity to the International Standards/Regional Standards, The PMRCL's Signaling Facility Plan, etc. In addition, JST has guessed some Japanese suppliers could participate in the PMRCL project for CBTC.
- On the other hand, JST has also guessed it would be difficult for Japanese suppliers to manufacture Signaling devices/equipment, such as the Electric Point Machine, because they have to conform to Regional Standards such as domestic Standards of IRS or RDSO.

#### (2) Telecommunication

- JST has confirmed a joint venture company between Indian and Japanese suppliers has manufactured fiber optic cables in India.
- In addition, there are many competitive suppliers in the telecommunications sector throughout the world, including India.
- Therefore, JST has confirmed that it would be difficult for Japanese suppliers to participate in the telecommunication sector of the PMRCL project.

### 26.2.3 AFC

- There are mainly two types of fare media used in AFC System worldwide, Type-A (ISO/IEC 14443) and FeliCa (ISO/IEC 18092).
- FeliCa is the Japanese Technology, and Felica enables fare collection for many passengers at limited spaces (by the number of limited automatic gates) because FeliCa can read and write twice as fast as Type-A and recognize a fare media with a broader range than Type-A.
- Therefore, FeliCa is the fare media suitable for urban railways with high passenger volumes, and most Japanese urban railways have introduced FeliCa and proven its high reliability.
- However, FeliCa and Type-A are not compatible, and NCMC that PMRCL plans to introduce conforms to Type-A. It means Felica and NCMC are not also compatible.
- In addition, JST has confirmed that there would be no technical concerns and requirements PMRCL couldn't solve without introducing FeliCa.
- There are many competitive suppliers in the AFC system sector throughout the world, including India, if FeliCa isn't required.
- Therefore, JST has confirmed that it would be difficult for Japanese suppliers to participate in the AFC system sector of the PMRCL project.

### 26.2.4 Electrical and Mechanical System/Facilities

- In an interview with manufacturers of electrical power products, it was found that Indian manufacturers are strong in AC equipment in India. However, the Scott-connected transformer is not manufactured by Indian company, and Japanese companies have an advantage. In addition, Japanese companies have a track record of introducing Scott-connected transformers on the Western Dedicated Freight Corridor, so this point also has an advantage. Although a Scott-connected

transformer has the feature of reducing voltage unbalance, it is generally 1.5 to 2 times more expensive than a Single-phase transformer. Therefore, it is important to consider the risks and costs caused by voltage unbalance and include it in the specification.

- Indian domestic companies are highly competitive in elevating equipment including lift and escalators. In recent years, Japanese companies have also stepped up their operations, but the installation is limited to specifications that require high safety and amenity such as luxury housing. Therefore it is difficult to use in public facilities due to the disadvantage in price competition.

### 26.2.5 Rolling Stocks

There are the following three possible methods of using Japanese technology for Rolling Stocks.

#### (1) Application of Advanced Japanese Systems or Components

Advanced Japanese systems or components are supplied to Indian car builders. The items to be supplied are propulsion system, auxiliary power supply system, TCMS, etc. The method has many examples of Indian metro projects, and it is reliable for the Indian rolling stock market.

#### (2) Cooperation with Indian Car Builder by Japanese Technology

The export of completed cars from Japan is disadvantageous in terms of competitive price power. Hence, cars designed in Japan may be assembled under Japanese quality control in cooperation with Indian car builders.

#### (3) Delivery of Completed Cars from Japan

As a leading step of above (2), there is a possibility of the completed car from Japan only for prototype. Delivery of all completed cars from Japan is unrealistic due to the cost issue.

### 26.2.6 Tunnel Boring Machine (TBM)

Japanese TBM technologies are numerous and also world-leading. Below companies are major Japanese TBM supplier company. One is JIM Technology Corporation (JIMT) other one is Underground Infrastructure Technologies Corporation (UGITEC) in Japan.

About JIMT

> JIM Technology Corporation (JIMT) was established by IHI Corporation (IHI), JFE Engineering Corporation (JFE), and Mitsubishi Heavy Industries, Ltd. (MHI) by integrating their businesses in shield tunneling machines. Taking advantage of the three companies' experience of having delivered 4,000 units and the synergy among them, we at JIMT aim to become a leading company in the global market.

Source: JIMT Home page, https://www.jimt.co.jp/en/company/02.html

About UGITEC

> Kawasaki Heavy Industries LTD, and Hitachi Zosen Cooperation integrated the TBM business and newly established "Underground Infrastructure Technologies Corporation"

Source: UGITEC Home page, https://ugitec.co.jp/en/company/history/

The below presentation slides show the proposals of Japanese TBM technologies for Patna Metro.

### (1) Japanese TBM technologies by JIMT;

1) The simultaneous excavation system

JIMT
JIM TECHNOLOGY CORPORATION

## JIMT) Simultaneous Excavation System

**1. Overview**

When we want to improve excavation and tunneling works more efficient and speedy, we have to

- ✓ increase excavation speed by high power and high rotation speed TBM,
- ✓ reduce downtime which caused by regular works such as conversion / maintenance and troubles, or
- ✓ **reduce Loss Time and Cycle Time for regular works such as assembling segments.**

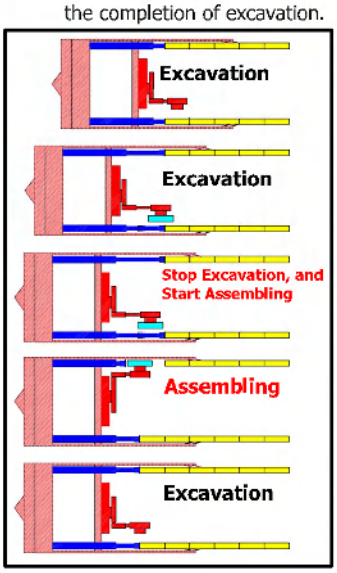
The Simultaneous Excavation System can reduce the Loss Time and Cycle Time by assembling segments during the excavation of shield tunneling. Undesirable changes in shield TBM attitude and the jacking rate (excavation speed) due to assembly operation are prevented by optimizing each jack pressure. By using this Automated Pressure Control method for balancing the moment of thrust force, thrust jacks can be retracted for assembling segments while excavating. The simultaneous Excavation method is a widely applicable, economical technology to increase the advance rate.

**2. Features**

**(1) Comparison of work flow**

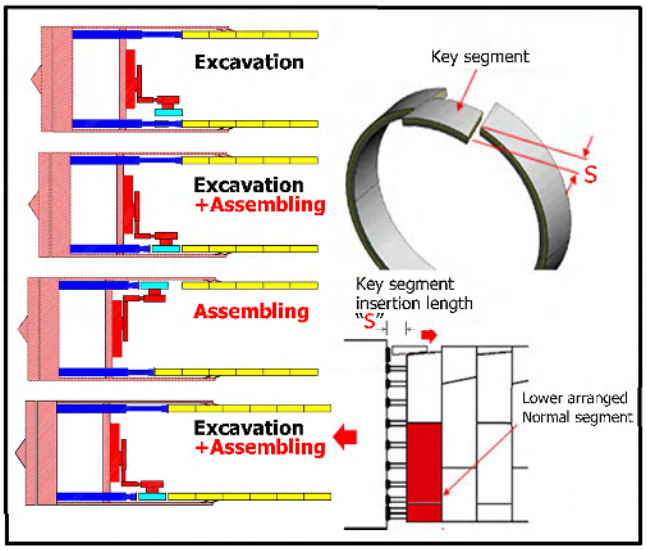
Standard Excavation

Segment assembling starts after the completion of excavation.




Simultaneous Excavation

Some segments can be assembled while excavation.



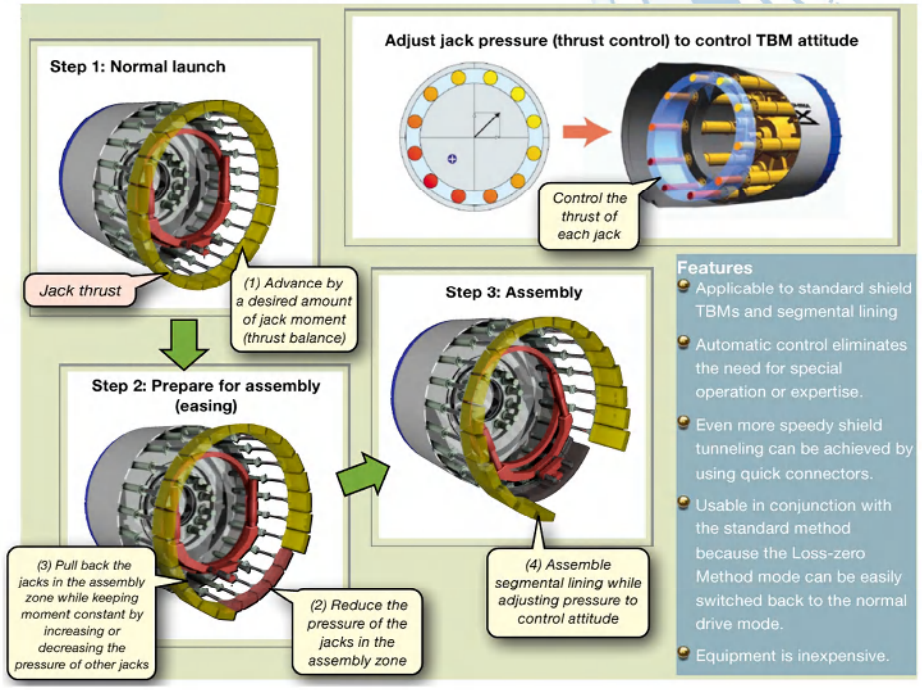

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1-14 Nisshin-cho, Kawasaki-ku,
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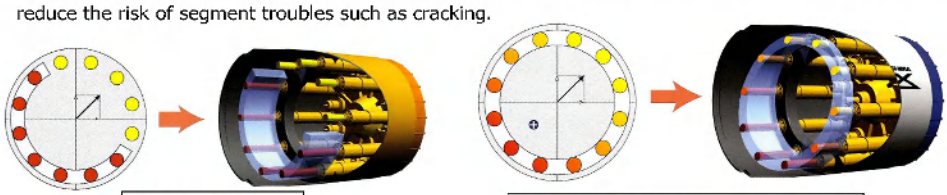
## (2) Simultaneous Excavation Procedure




## (3) Technologies

### a) Automated Moment Control Method

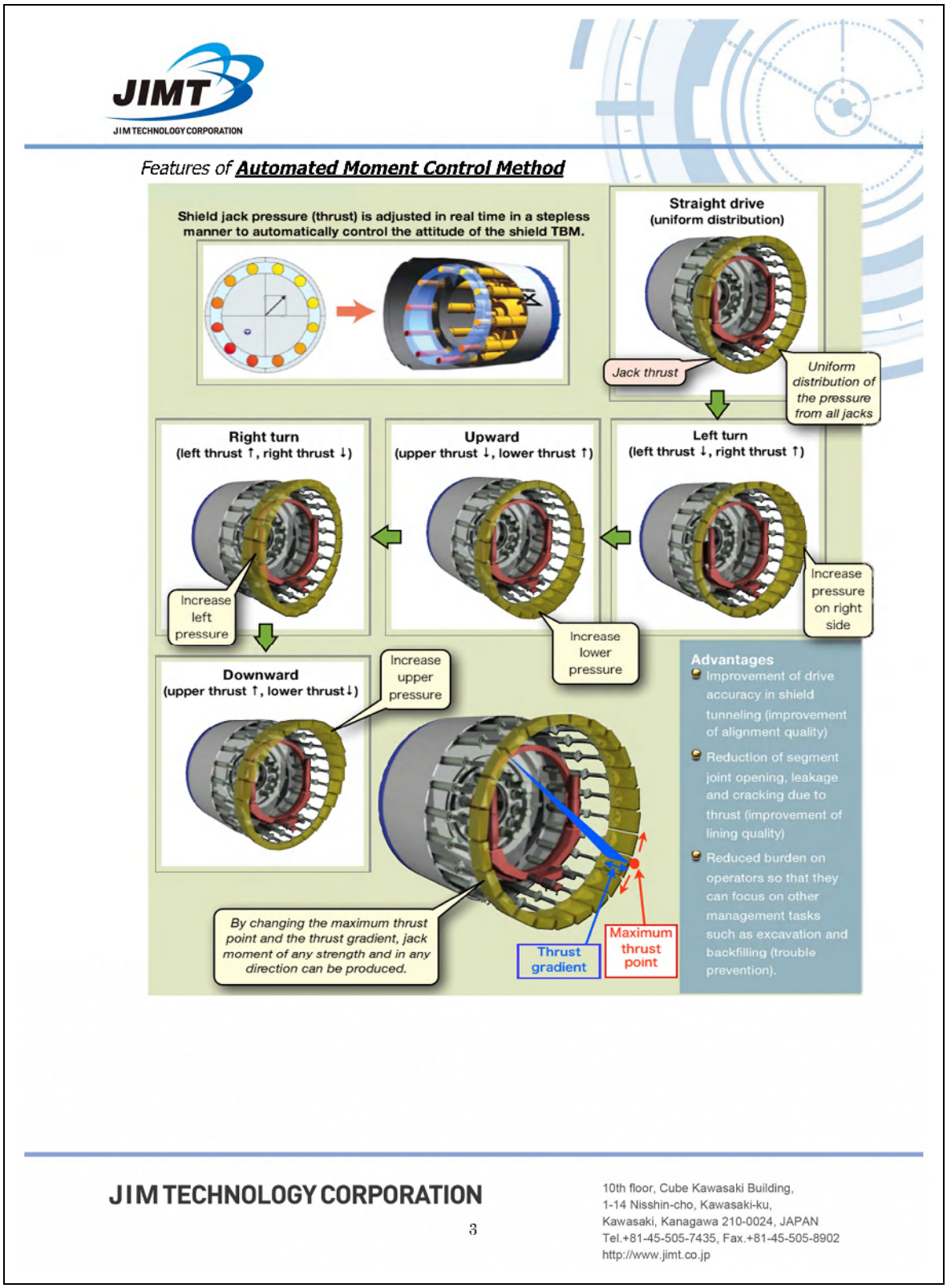
To control the directions of TBM, we adjust the TBM attitude by selecting thrust jacks to be increased/decreased pressures and changing the moments. The moment Control Method can change the moments by adjusting thrust jacks pressure individually and automatically in real time. Accurate automatic directional control can be achieved because jack moment of any strength and in any direction can be set quickly. Therefore, the moment Control Method can improve tunnel alignment quality and reduce the risk of segment troubles such as cracking.



Standard Method
(Thrust Jack Select Control)

Automated Moment Control Method
(Individual and Automated Pressure Control)

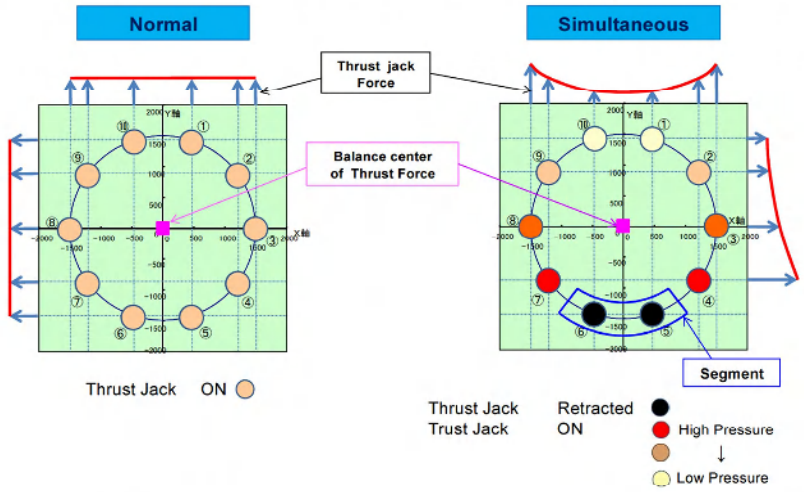
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Features of Automated Moment Control Method
Shield jack pressure (thrust) is adjusted in real time in a stepless manner to automatically control the attitude of the shield TBM.
Straight drive
(uniform distribution)
Jack thrust
Uniform distribution of the pressure from all jacks
Right turn
(left thrust ↑, right thrust ↓)
Upward
(upper thrust ↓, lower thrust ↑)
Left turn
(left thrust ↓, right thrust ↑)
Increase left pressure
Increase lower pressure
Increase pressure on right side
Downward
(upper thrust ↑, lower thrust ↓)
Increase upper pressure
By changing the maximum thrust point and the thrust gradient, jack moment of any strength and in any direction can be produced.
Thrust gradient
Maximum thrust point
Advantages
Improvement of drive accuracy in shield tunneling (improvement of alignment quality)
Reduction of segment joint opening, leakage and cracking due to thrust (improvement of lining quality)
Reduced burden on operators so that they can focus on other management tasks such as excavation and backfilling (trouble prevention).
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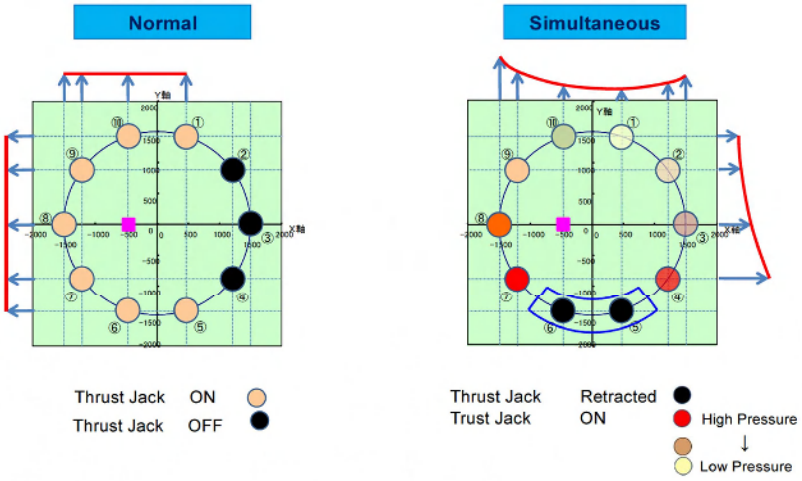
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## *Flexible Jack Pressure Control*

Excavation Straight




Excavation Right Curve




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2) Obstacle Cutting Technology

# Obstacle Cutting Technology

JIMT

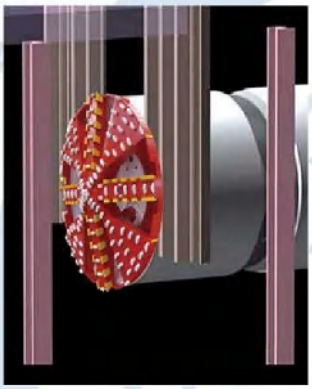
**1. Purpose**

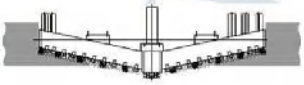
In case excavation in urban area by shield tunneling method, we some time encounter the obstacle like PC-Pile, Wood Pile, Concrete Wall, etc. If we can predict or assume these situations beforehand, we can take care of the specification and the device of machine.

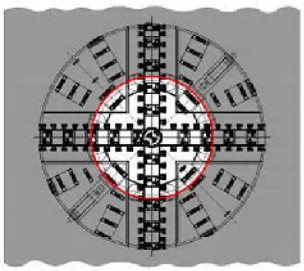
Here JIMT explains our special countermeasure and treatment.

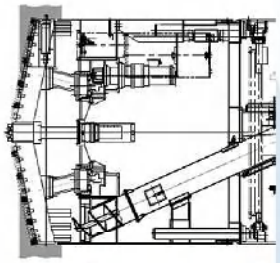
**2. Inclined Cutter Head Design**

In order to reduce reaction cutting torque and to avoid the clogging of evacuation system, we apply "Inclined Cutter Head Design". Feature of this is "Step by Step Cutting" from center part to circumference.









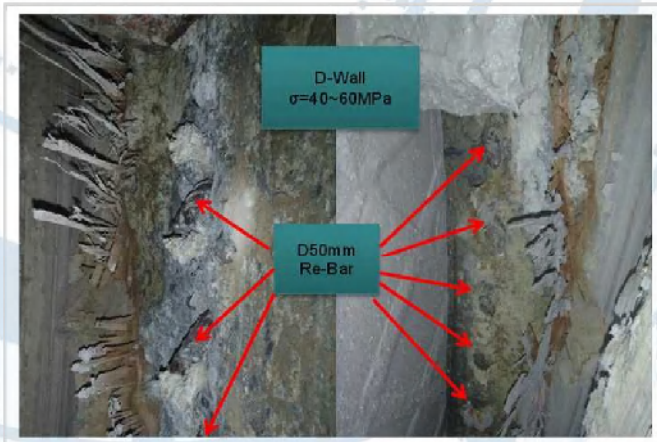
**Special Cutting Tools**

Depend on character of obstacle, JTSC carefully select the "adequate cutting tools" in accordance with our rich experience. Below are some samples.





Obstacle Cutting-Bit




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JIMT

## 3. Other Treatment

Mainly JTSC consider below points.

1) Bit layout and number
2) Prevention of material clogging to cutter and evacuation system
3) Precise control of advance speed
4) Secure the machine damage by obstacle
5) Safety work and operation



2.68m EPB Obstacle Cutting Type



2.69m SLURRY Obstacle Cutting Type



2.78m EPB Obstacle Cutting Type



4.24m EPB Obstacle Cutting Type



4.68m EPB Obstacle Cutting Type



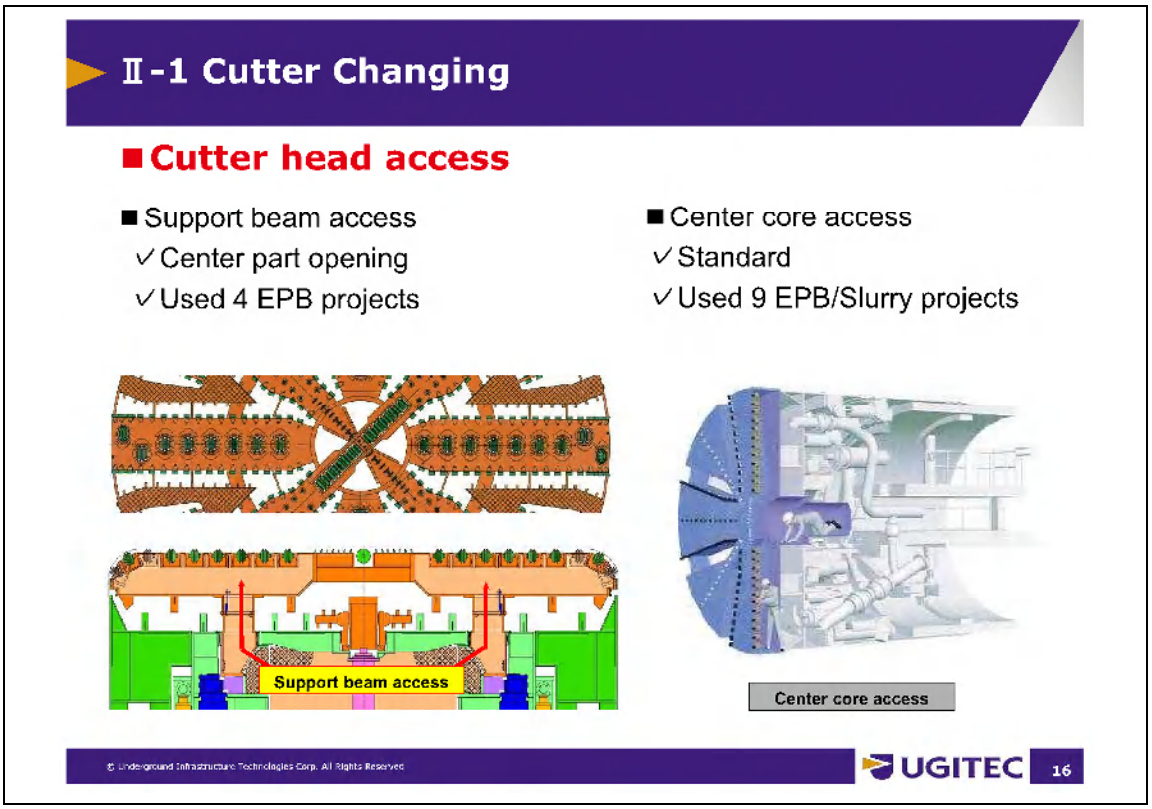
6.44m EPB Obstacle Cutting Type

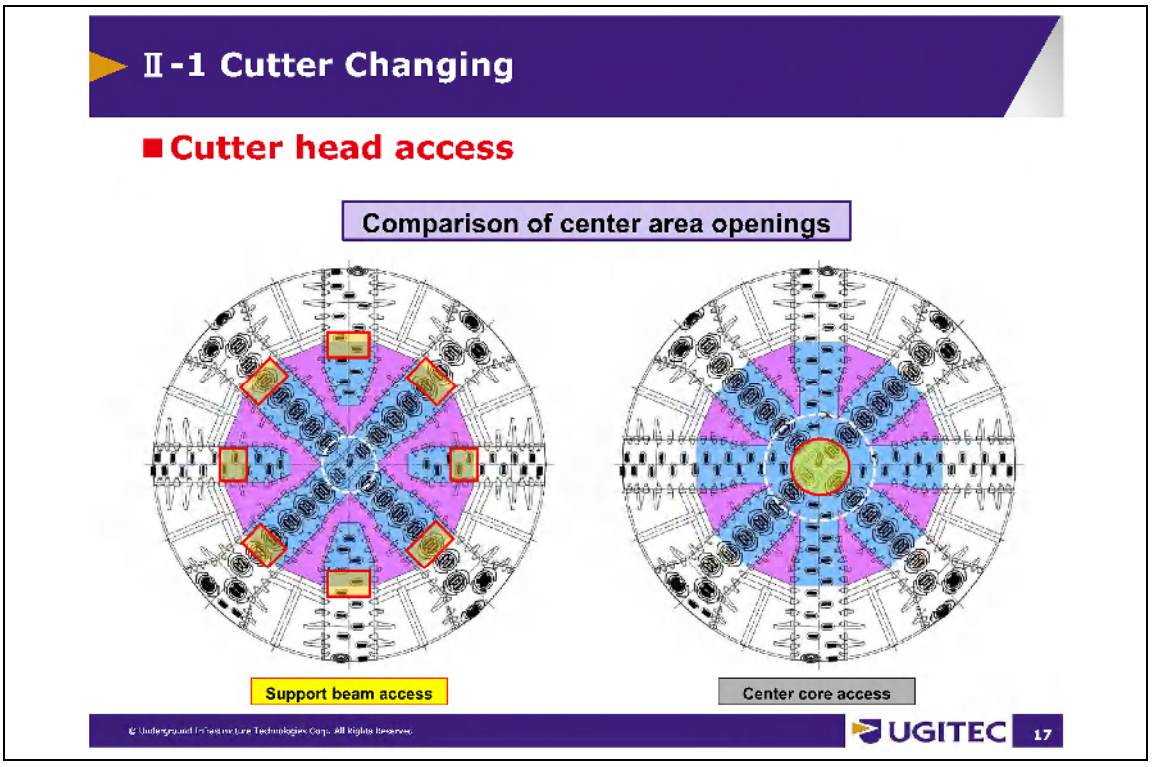
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## (2) Japanese TBM technology by UGITEC

1) Cutter Changing

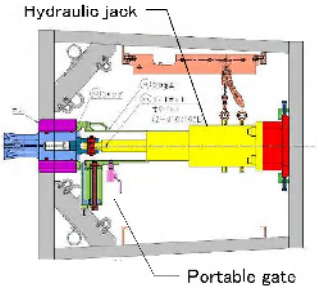


## Ⅱ-1 Cutter Changing

### ■Portable gate type for Pre-cutting bit






✓1.0MPa pressure test
✓1hr for 1 cutter changing
✓Actual record ; 9 projects

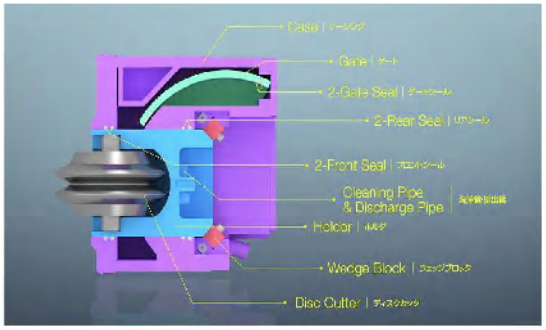


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## Ⅱ-1 Cutter Changing

### ■Rotary gate type for DRC

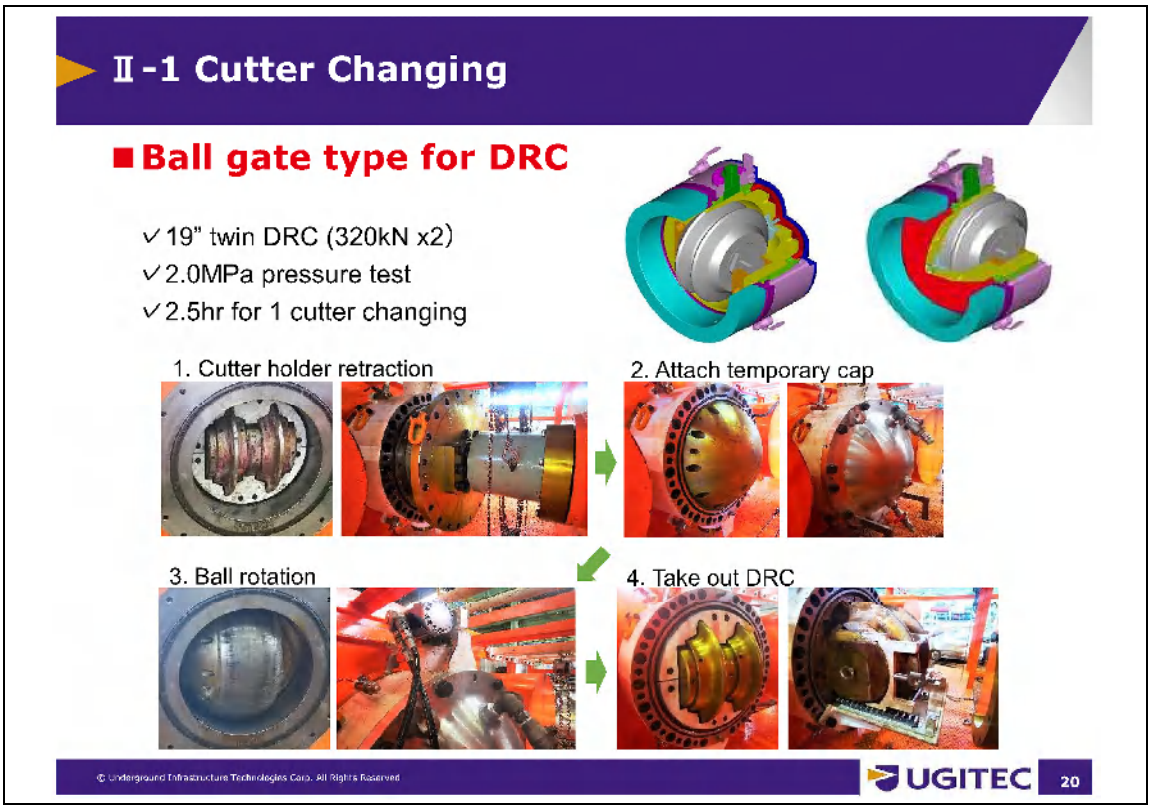




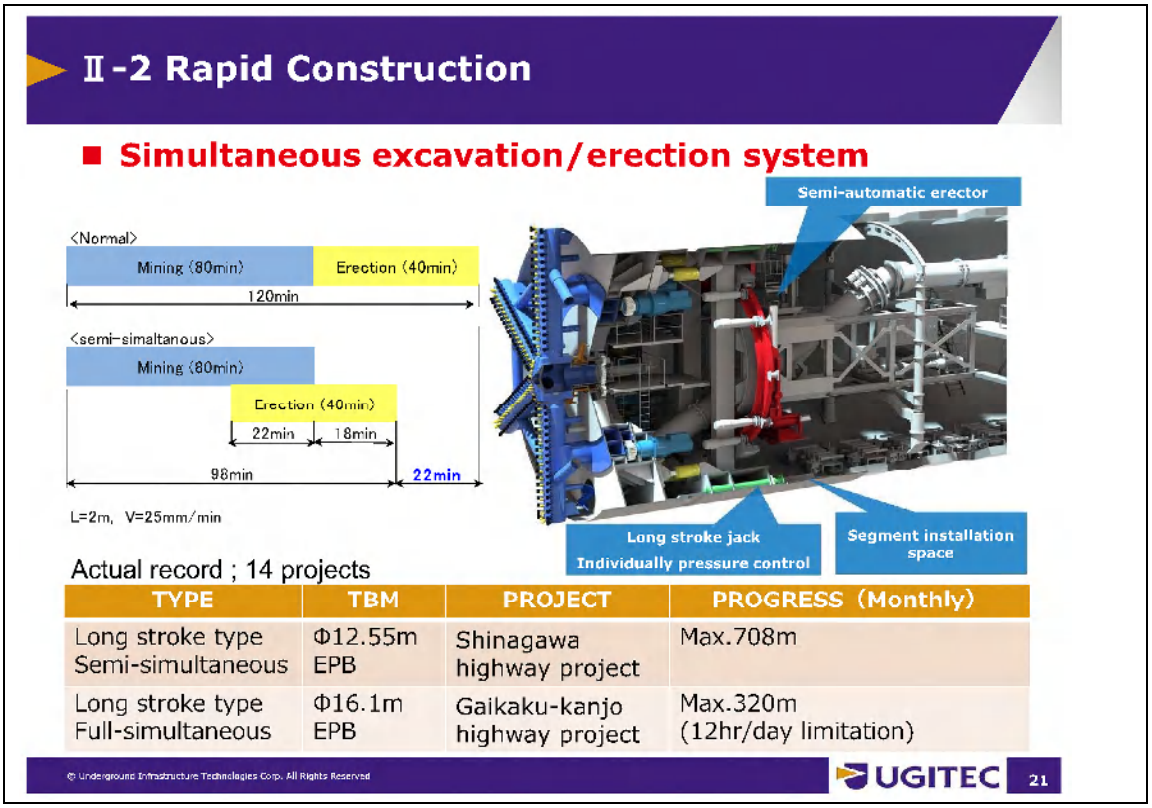

✓17" double DRC (250kN)
✓1.0MPa pressure test
✓2.5hr for 1 cutter changing
✓Actual record ; SR99 17.45m EPB



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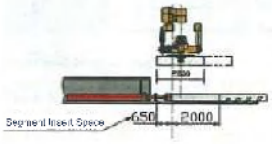
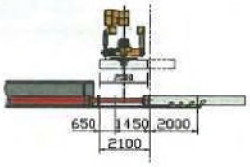
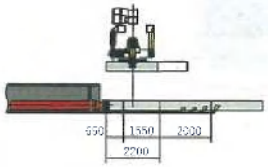
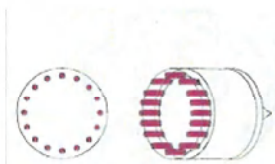
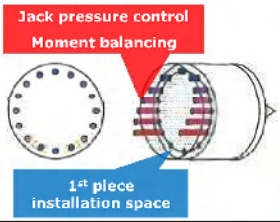
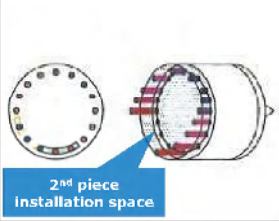



2) Rapid Construction



## Ⅱ-2 Rapid Construction

### ■ Simultaneous excavation/erection system

| Mining start (excavation speed 40mm/min) | Start simultaneous excavation 1st piece erection | Under simultaneous excavation 2nd piece erection |
|---|---|---|
| Thrust jack ST: 0mm | Thrust jack ST: 1450mm | Thrust jack ST: 1550mm |
|   |   |   |
|  |   |   |

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