001.32.3

MINISTRY OF TRANSPORT AND INFRASTRUCTURE
OF THE REPUBLIC OF TÜRKİYE
GENERAL DIRECTORATE OF
INFRASTRUCTURE INVESTMENTS

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MINISTRY OF TRANSPORT AND INFRASTRUCTURE
GENERAL DIRECTORATE OF INFRASTRUCTURE INVESTMENTS
DESIGN TECHNICAL SPECIFICATION

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ABBREVIATIONS

ABBREVIATION	ENGLISH
ABS	Acrylonitrile Butadiene Styrene
AC	Alternating Current
ACB	Air Circuit Breaker
AFIL	Audio-frequency Induction Loop
AG	Low Voltage
AL	Aluminium
ANSI	American National Standards Institute
APCO-25	Association of Public Safety Communication Officials – Project 25
AREMA	American Railway Engineering and Maintenance-of-Way Association
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineer
ASTM	American Society for Testing and Materials
ATC	Automatic Train Control
ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATS	Automatic Train Supervision
AYGM	Directorate General of Infrastructure Investments
BCB	Battery Charger Board
BDT	Building Condition Assessment
BN	Relative Humidity
BRA	Building Risk Analysis
BS	British Standard
BYKHY	Turkey's Regulation on Fire Protection
CAT	Category
CBTC	Communications-Based Train Control
CCTV	Closed-Circuit Television
CE	Conformité européenne
CEN	European Committee for Standardisation
CENELEC	European Committee for Electrotechnical Standardization
CESB	Central Emergency Stop Button
CFD	Computational Fluid Dynamics
CLC / TR	European Committee for Electrotechnical Standardization Technical Report
CP	Cross Passage

ÇYTHYEY	Regulation Amending the Regulation on the Design, Calculation and Construction Principles of Steel Structures
ACH	Air Chang eper Hour
dB	Desibel
dBA	Desibel (A)
DC	Direct Current
DIN	German Standards Institute
DOR	Depot Operation Room
ECS	Environmental Control System
EIA	Electronic Industries Alliance
EM	Emergency Mode
EMC	Electromagnetic Compatibility
EMO	Chamber of Electrical Engineers
EN	European Standards
EPABX	Electronic Private Automatic Branch Exchange
EPB	Earth Pressure Balance
ESB	Emergency Stop Button
ETSI	European Telecommunications Standards Institute
EXF	Exhaust Fan
FAP	Fire Alarm Panel
FHWA	Federal Highway Administration
FPS	Frame Per Second
GIS	Gas-Insulated Switchgear
GNSS	Global Navigation Satellite System
GoA	Grade of Automation
GPS	Global Positioning System
GRC	Ground Reaction Curve
GSI	Geological Strength Index
GSM	Global System for Mobile Communications
HDPE	High-Density Polyethylene
HFFR	Halogen-Free Flame Retardant
HRV	Heat Recovery Ventilator
HYYİ	Tactile Guide Surfaces Or Warning Surfaces
Hz	Hertz
I/O	Input / Output
IAC	Internal Arc Classification

IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IES	Illuminating Engineering Society
IGBT	Insulated Gate Bipolar Transistor
IHF	Station Ventilation Fan
IK	Impact Protection
IP	Ingress Protection
ISO	International Organization for Standardization
ITA	International Tunnelling Association
ITU	International Telecommunications Union
OHS	Occupational Health and Safety
kA	Kiloamper
KGM	General Directorate of Highways (Türkiye)
kPa	Kilo pascal
DB	Dry Bulb
kV	Kilovolt
kW	Kilowatt
LCD	Liquid Crystal Display
LCP	Local Control Panel
LED	Light Emitting Diode
LHD	Linear Heat Detection
LSHF	Low Smoke Halogen-Free
LSZH	Low Smoke Zero Halogen
LVS	Low Voltage Switchboard
mA	Miliamper
MCB	Miniature Circuit Breaker
MCC	Motor Control Centre
MCCB	Molded Case Circuit Breaker
MDE	Maximum Design Earthquake
MSC	Manual Cabin Signalling
mWG	Meter Water Gauge
MVA	Megavoltamper
MW	MegaWatt
NATM	New Austrian Tunneling Method
NEMA	National Electrical Manufacturers Association
NF	French Standard

NFPA	National Fire Protection Association
Ni-Cd	Nickel-Cadmium
NTP	Network Time Protocol
°C	Celsius Degree
OCC	Operational Control Centre
ODE	Operation Design Earthquake
OG	Medium Voltage
PA	Public Address
Pa	Pascal
PABX	Public Address Branch Exchange
PSDS	Platform Screen Door System
PAL	Phase Alternate Lines
PCS	Power Control System
PESB	Platform Emergency Stop Button
PLC	Programmable Logic Controller
PM	Metal Partitioning
PoE	Power over Ethernet
PPM	Parts Per Million
PPRC	Polypropylene Random Copolymer
PTZ	Pan, Tilt, Zoom
PVC	Polyvinyl Chloride
Q	Rock Support Classification System
RAMS	Reliability, Availability, Maintainability, Safety
RCBO	Residual Current Circuit Breaker with Over-Current Protection
RCD	Residual Current Device
RGB	Red Green Blue
RIO	Remote Input/Output
RMR	Rock Mass Rating
RMS	Root Mean Square
RPM	Rotate Per Minute
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SCC	Surface Characteristic Curve
SIL	Safety Integrity Level
SLS	Service Limit Status
SMP	Surface Monitoring Point

SOR	Station Operation Room
SPL	Sound Pressure Level
STI	Speech Transmission Index
TBDY	Turkish Building Earthquake Regulations
TBM	Tunnel Boring Machine
TCDD	State Railways of the Republic of Türkiye
TCP/IP	Transmission Control Protocol / Internet Protocol
TCRP	Transit Cooperative Research Programme
TEDAŞ	Turkey Electricity Distribution Corporation
TEİAŞ	Turkish Electricity Transmission Corporation
TETRA	Terrestrial Trunked Radio
TVS	Tunnel Ventilation System
TIA	Telecommunications Industry Association
TS	Turkish Standard
TSE	Turkish Standards Institute
TVF	Tunnel Ventilation Fan
UDP/IP	User Datagram Protocol
UIC	Union Internationale des Chemins de fer
ULS	Ultimate Limit State
UPS	Uninterruptible Power Supply
UTO	Unmanned Train Operation
UV	Ultraviolet
VDE	Association for Electrical, Electronic and Information Technologies
VLAN	Virtual Local Area Network
VLD	Voltage Limiting Device
VRF	HVAC Technology with Variable Refrigerant Flow/Volume
XLPE	Cross-linked Polyethylene
GWL	Ground Water Level
WB	Wet Bulb

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1. GENERAL PRINCIPLES

The general principles to be taken into account in designs are listed below.

- All designs shall be carried out in accordance with current regulations in force.
- Subject to approval by the Authority/Engineer, current international regulations may be used in addition to or in place of national regulations.
- In all cases, the prepared projects shall contain details that meet the criteria of verifiability and constructability.
- Projects shall be submitted for approval in four signed copies.
- Prior to commencing the designs, a report on the design criteria for each discipline shall be prepared in accordance with the conditions specified in this specification, and approval from the Authority/Engineer shall be obtained.

1.1. SCOPE

The General Directorate of Infrastructure Investments plans to complete the construction of the Istanbul Northern Ring Railway Project through five separate tenders.

- Design Works, construction works, power supply, electrification, tunnel electromechanical works and remote-control works are planned to be tendered in four separate lots. Two lots shall be located at the two ends of the project, whilst the other two lots will be situated in the central parts of the project. The contractor for each lot will be responsible for the completion of construction and electrification works within their own lot, as well as ensuring the connection of the railway systems with those of existing and/or adjacent lots.
- Signalling, telecommunications and support systems will be tendered as a single package covering the entire project and will have a single contractor. The contractor shall be responsible for the design, software, supply of materials, installation, dismantling, labour, transport, trial operation and commissioning of the Istanbul Northern Railway project—which connects at one end to the existing railway lines via the Gebze-Çayırova triple tracks and at the other end to the existing railway via the Çatalca triple tracks—to ensure it operates as a whole under the required conditions, and for the installation and commissioning of signalling, telecommunications and support systems with interfaces provided for integration with the existing lines.

Design services shall be carried out by each of the five contractors in accordance with the scope specified below covering all works included within their respective scopes.

All construction and installation work under Package 1 will be delivered under a Design and Build approach in accordance with the FIDIC Conditions of Contract for Building and Engineering Works Designed by the Contractor (Yellow Book, Second Edition 2017, reprinted 2022 with amendments).

Under each Lot, the design obligations shall cover, as a minimum, the following deliverables for submission and approval by the Engineer:

- Preliminary Design: Alignment and Geodetic Works.
- Preliminary Design: Civil and Structural Works.
- Preliminary Design: Station Works, and Electromechanical, where applicable to the Lot.
- Mapping & Soil Investigation Works
- Detailed Design: Alignment and Geodetic Works.
- Detailed Design: Geological and Geotechnical Works.
- Detailed Design: Civil and Structural Works.
- Detailed Design: Track and Superstructure Works.
- Detailed Design: Power Supply, Distribution, and Electrification Works.
- Detailed Design: Tunnel Electromechanical Works.
- Detailed Design: Station Works, and Electromechanical, where applicable to the Lot.
- As-Built Documentation: All Disciplines.

The above deliverables represent the minimum expected scope of design services under each Lot. In delivering the detailed design, the Contractor shall carry out all tasks typically required for an infrastructure rail project of this nature, including but not limited to: geodetic survey works; collection of all information on existing and planned infrastructure and substructures that may affect or be affected by the alignment, including gas lines, electrical and communication lines, sewage systems, water supply lines, and other utilities; site investigations and geological and geotechnical assessments; horizontal and vertical alignment design; hydrological, hydraulic, and drainage studies and design, including identification of necessary hydraulic structures and obtaining approvals from the General Directorate of State Hydraulic Works (DSİ — Devlet Su İşleri); track superstructure design; design of civil structures along the line; detailed design of passenger stations covering civil, architectural, electromechanical, and systems integration aspects; power supply, traction, and electrification design; tunnel electromechanical systems design; Building Information Modeling (BIM) in accordance with Chapter 4, Section 4.9; and preparation of as-built documentation.

Each contractor shall be responsible for completing the design and construction works in such a way that the design of the works under their responsibility ensures the Istanbul Northern Ring Railway provides uninterrupted and integrated service as a whole, and provides the necessary interfaces and connections to enable their section and the subsequent sections and/or existing systems.

All design services defined in this specification shall encompass the five contractors identified above and shall be executed in a manner that maintains overall system integrity.

A separate single contract (Package 2) will be awarded for the design, installation, and construction of signaling, telecommunication, and supporting systems for the entire INRAIL project. Package 2 is not part of this tender. Civil works Contractors under Package 1 shall

treat the Package 2 contractor as a primary interface party from the outset of design, in accordance with Employer's Requirements Chapter 4 and Section 4.5. For further details, refer to Section 5.3.5 of the Employer's Requirements and other relevant sections.

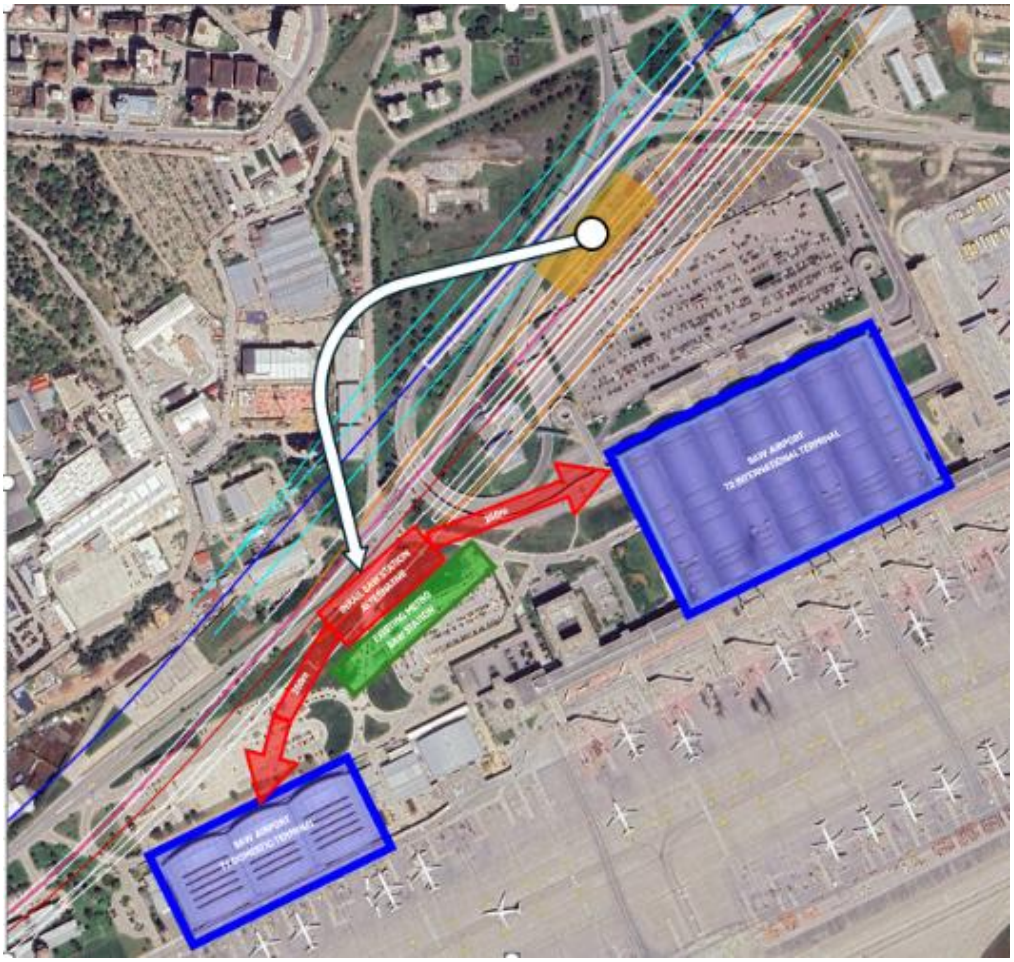
1.2. ALTERNATIVE DESIGN STUDIES

1.2.1. Siding Lines

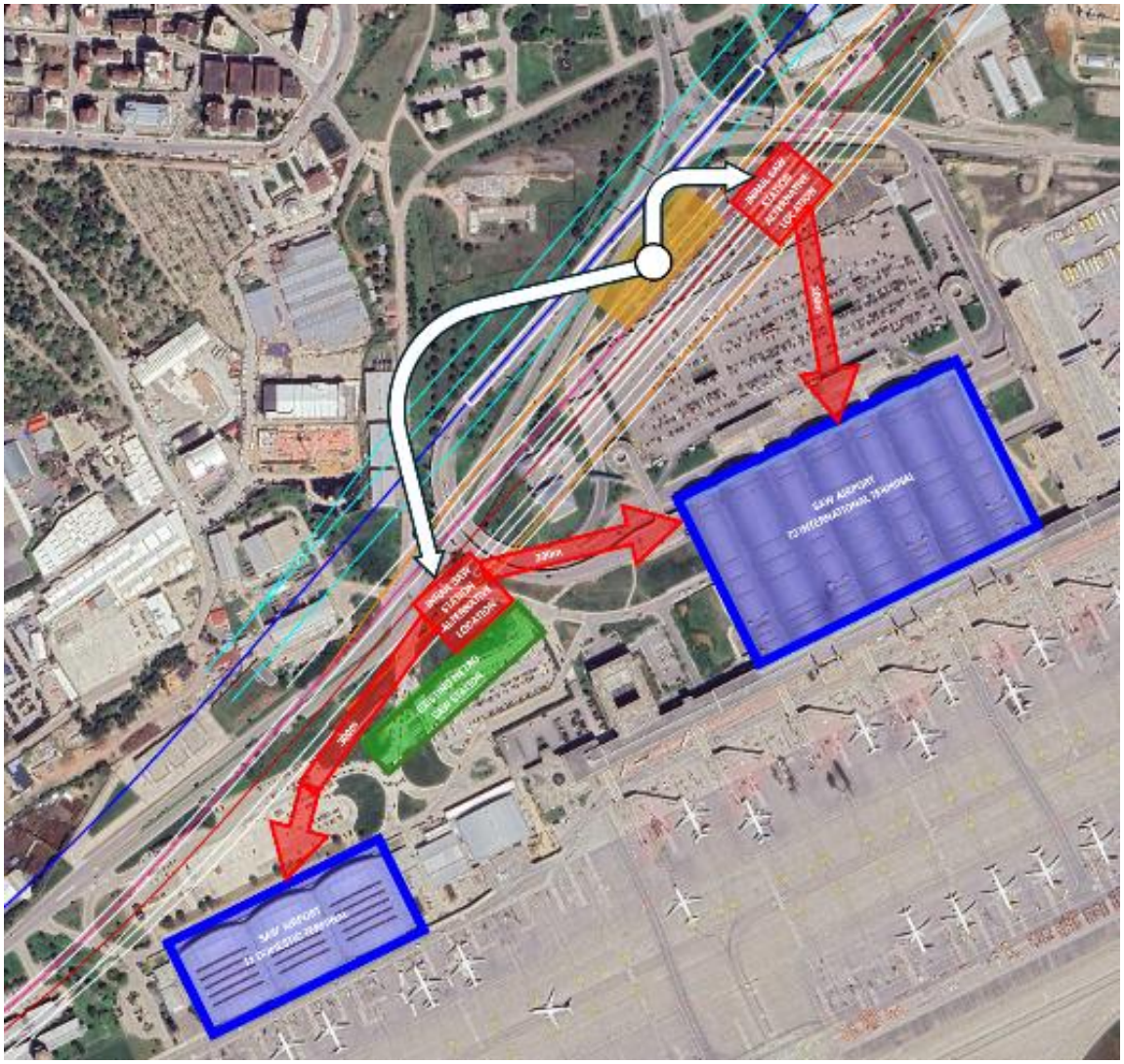
Contractors awarded for lot 2 and lot 3 shall prepare alternative studies to evaluate the potential use of safety tunnels for passangers at km 44 & 57 before the Yavuz Sultan Selim Bridge as both train siding and safety tunnel for passangers by relocating the turnouts accordingly to increase the capacity and to improve the operability of the system.

1.2.2. Sabiha Gökçen Airport Station

The Contractor awarded for lot 1 shall prepare alternative studies for Sabiha Gökçen Airport Station to improve the passanger access and transfer capabilities. Illustrative visuals of potential alternatives are provided below. However, alternative studies to be conducted shall not be limited to these.



As Alternative-1, the station could be configured as a single concourse structure set back by approximately 400 m.



As Alternative-2, the station could be configured with a concourse structure at each end, set back by approximately 150 m.

1.3. MAPPING

1.3.1. Cartography

A 1:5000-scale topographic map will be produced based on the evaluation of aerial photographs, in accordance with the provisions of the Regulation on the Production of Large-Scale Maps and Cartographic Information and the Regulation on the Provision and Use of Maps and Cartographic Information.

As-built map works will be carried out in accordance with the current Large-Scale Map and Map Data Production Regulation, using a 1:1000 scale as the basis, to cover all details including the topographical conditions of the land where the route project is planned; the maps produced will be linked to the national elevation and coordinate system.

Key considerations during the preparation of the existing map:

- Preparation of a 1:25,000-scale triangulation, chain survey, and main levelling network grid,
- Preparation of the 1:10,000 scale polygon network,
- Numbering of facilities associated with ground control points in accordance with the current Large-Scale Map and Map Information Production Regulation,
- Measurements and calculations to be based on the TUTGA (Turkish National Basic GPS Network),
- The use of the grid elevation (plankote) technique with detail points approximately every 5 metres,
- In Sabiha Gökçen Airport Station, all trees shall be indicated and trees with a diameter greater than 20 cm shall be identified by species on the map. Utility manhole covers shall be surveyed, and the responsible authority shall be indicated on the map, poles and cable routes of overhead electrical and power lines shall be indicated, including their projections and elevations.

and other such matters will be taken into account.

1.3.2. Triangulation, Polygon and Levelling Network

Ministry of National Defence, Ministry of Finance, Ministry of National Education, Ministry of Environment and Urbanisation, Ministry of Food, Agriculture and Livestock, Ministry of Culture and Tourism and their affiliated units, TCK, DSİ, MTA, TEİAŞ, TEAŞ, PTT, Türk Telekom, Municipalities, İlbank A.Ş. Plans and maps belonging to the General Directorate of Land Registry and Cadastre (TKGM) and its affiliated units, Provincial Special Administrations, Organised Industrial Zones (OSB), universities and other institutions and organisations will be assessed, and all structures located on or beneath the land will be shown on the map.

Facilities planned for construction by the relevant institutions or for which an approved project exists will be represented on the map using a faded display.

To assist in the project design phase, the project site’s existing and approved 1/5000 Master and 1/1000 Detailed Zoning Plans (if available) will be obtained from the relevant municipality; the cadastral base map and zoning plan sheets will be overlaid onto the existing map, and coordinate transformation calculations will be performed if necessary.

Prior to commencing field surveying, proposed triangulation points and polygons at appropriate intervals, utilising existing data, shall be plotted on 1:10,000 scale maps and survey lines shall

be prepared. These survey lines shall be submitted to the Authority for approval, and once approval is obtained, the establishment of points in the field shall commence.

The nature and number of these points shall be determined with the Authority's approval in accordance with the Large-Scale Map and Map Data Production Regulations, and all necessary coordinate system transformation values shall be established.

The ground control (triangulation and polygon) points to be used during the production of the current map must be established in such a way as to minimise their susceptibility to interference from infrastructure and parcel works.

A network of ground control points not approved by the General Directorate of Land Registry and Cadastre (TKGM) and/or its relevant units shall also be deemed not accepted by the General Directorate of Surveying and Mapping (AYGM).

1.3.3. Surveying

GPS, triangulation-based, polygon-based, polar measurement methods for detail acquisition (Total Station) or photogrammetry-based measurement methods may be used subject to the approval of the AYGM.

For 1:10,000 scale maps, triangulation, levelling network and related calculations, blueprints, control point sketches and calculation summaries shall be prepared. Control point sketches shall also include a photograph of the facility point. The calculation summaries and survey sketches shall be compiled in one volume, whilst all measurements and calculations pertaining to the triangulation and levelling networks shall be compiled in a separate volume; these shall be submitted to TCDD with the approval of TKGM.

A 1:1,000 scale strip map of the corridor, with a total strip width of 600 m, shall be prepared. The strip width may be increased or reduced at locations deemed necessary by the Authority. Where photogrammetric methods are used, details that cannot be interpreted in the photogrammetric assessment (such as locations planned for engineering structures, bridges, viaducts, tunnels, stations, etc.) shall be integrated into the terrain using terrestrial methods.

During the route design phase, where the Authority deems it necessary in areas containing engineering structures, topographic surveys shall be commissioned at a scale to be determined by the Authority.

1.3.4. Site Inspections

Following the production of the as-built map and the completion of office checks, a site inspection of the as-built map shall be carried out on a date agreed between the Authority and

the firm. During the inspection, the surveying engineer responsible for the production of the as-built map shall be present on site.

During the inspection, instruments, measurement and evaluation methods of at least the same quality and precision as those used in production shall be employed. In areas with varying levels of detail, at least 10% of the sheets distributed across the project area shall be compared with the on-site details to verify whether all details are present on the sheet and whether the contour lines correspond with the topography.

Maps shall be delivered in digital format (NCZ, DWG, DXF, DGN, SHP) in the formats specified by the Authority, both as a complete set and divided according to the National Sheet System; in printed form, they shall be delivered as three sets printed on standard map paper. If requested by the Authority, one copy shall also be supplied printed on a 120- -micron polyester backing. In this case, two sets shall be printed on standard map paper.

The digital data contained on the CD/DVD shall not only contain graphical values but also actual elevation and coordinate values.

The rights to publish and use the produced maps and other information belong solely to AYGM. No copies may be reproduced, used, sold or distributed without the permission of the Contracting Authority.

1.4. SOIL INVESTIGATIONS

Sufficient ground investigations will be carried out to ensure that all structures to be constructed under the project are designed in accordance with current regulations and specifications; the following minimum conditions must be met:

- For linear continuous engineering structures (tunnels, embankments, cuttings, retaining walls, etc.), ground investigation boreholes will be carried out such that the distance between them is a maximum of 200 metres.
- For underpasses and large-scale culverts (greater than 3x3m), a minimum of one ground investigation borehole shall be carried out. Where the structure is oblique and consequently has a long span, additional boreholes may be requested by decision of the Authority/Consultant.
- One ground investigation borehole shall be carried out at each foundation of structures such as overpasses, bridges and viaducts. Where ground conditions vary signifisuperelevationally, the number of boreholes at the same foundation may be increased by decision of the Authority/Consultant.
- For station-type structures, a minimum of 3 boreholes for each concourse structure shall be carried out per station.

The depth of the boreholes to be carried out, the samples to be taken, and the field and laboratory tests to be conducted as per TS EN ISO 22476 and TS EN ISO 17892 respectively, as well as the criteria relating to the contractor's responsibilities, shall be determined in accordance with the AYGM Soil Investigation Technical Specifications (2018), which forms part of the tender documentation. Prior to commencing ground investigation works, the contractor shall submit an investigation programme, and the necessary works shall be carried out in accordance with the approval of the Authority/Consultant. The Engineer has to review and approve the Sıte Investigation Programme in 14 days.

In addition to the ground investigation programme, the Contractor shall carry out dedicated risk assessments addressing the following formation-specific geotechnical risks: dissolution and void risk, lithological variability, gas risk, unconsolidated and swelling ground, weak and weathering-sensitive horizons, and liquefaction. Each risk shall be individually assessed in relation to the specific geological formations encountered along the alignment, with mitigating measures incorporated into the detailed design.

The Contractor shall prepare and get approval for Geological and Geotechnical Report including but not limited to borehole logs; laboratory test results; interpreted ground model; geotechnical design parameters by formation; and risk assessment for each structure type. The approval of the Geological and Geotechnical Report shall precede and be a condition for the submission of structural designs for all related structure types, including tunnels, underground stations, retained structures, bridges, and viaducts. The Contractor's design programme shall reflect this sequencing explicitly, with geotechnical report approval shown as a predecessor activity to all related structural design submissions.

1.5. 1/1000 SCALE ROUTE STUDIES

Taking the approved corridor into account, the project route will be determined at a scale of 1/1000 for the horizontal alignment and 1/100–1/1000 for the vertical alignment.

Horizontal and vertical alignment sheets shall be prepared in sections of no more than 15 metres each and in folded form.

In route studies:

- Geometric standards
- Earthworks (Excavation)
- Tunnels, bridges, viaducts, engineering structures, agricultural underpasses and overpasses,
- Railway and service road drainage,
- Landscaping, aesthetics and their relationship with EIA,
- Land use, expropriation, property status and compliance with development plans,
- Maintenance and operational conditions

- Traffic safety,
- Future planning for the railway,
- Construction costs,
- Geotechnical requirements, etc., must be taken into account.

Route projects shall be prepared in accordance with current regulations and submitted to the administration for approval, accompanied by a horizontal-vertical alignment report prepared in accordance with the criteria set out below.

- The economic and social contributions of the project route to the area it will serve should be outlined in general terms,
- Information regarding the project criteria must be provided,
- Key features such as settlements, structures, cemeteries and agricultural areas encountered during the route survey must be explained,
- The current expropriation and planning status along the route, as well as any additional expropriation and planning amendments required under the project, must be explained,
- The condition of existing bridges, their renovation and the justifications therefor must be specified following consultation with the Directorate of the Civil Engineering Projects Branch,
- In addition to the general ground investigation along the route, information must be provided regarding the ground structure, potential issues that may arise during construction, and their solutions, particularly in sections involving deep cutting and filling,
- Should any changes be required to the corridor defined for the route subject to the tender, such changes must be explained along with their reasons,
- Where sections such as embankments, soil reinforcement, viaducts, tunnels and cuttings exist along the route that could serve as alternatives to one another, the reasons for the proposed structure must be stated following a comparison of economic and social factors,
- It must be investigated whether reinforcement and diversion are required in sections of the route where it crosses a river or enters the sea; if deemed necessary, information must be obtained by reviewing any previous works carried out by the General Directorate of State Hydraulic Works (DSİ) and the General Directorate of Infrastructure Investments, and this must be included in the report.
- Information should be provided regarding the proposed station locations, which are to be further detailed and approved.
- Information must be provided regarding special service structures located within the route's path (such as ENH, railway, and oil pipelines).
- Photographs of locations along the route that are of particular significance (such as critical sections, etc.) should be included.
- The standards of the proposed route must be described.
- Cross-sections of the project's horizontal alignment (in digital format) and satellite imagery must be submitted in digital format.

- The horizontal and vertical alignments must include the following representations:
- Horizontal curves must be selected according to the design speed
- Maximum superelevations must be determined in accordance with standards, taking into account the design speed, curve radius, climatic conditions and topographical features. The superelevation values to be applied ( ) will be calculated in accordance with the route criteria set out in AYGM and international regulations.
- Horizontal curves shall be defined by curve data. Curve data shall be defined by the horizontal curve radius (R), clotoid parameter (A), clotoid length (Ls), curve deviation angle (D, in degrees), tangent length (T), curve length (L), and curve coordinates (X=North, Y=East).
- Elevation and coordinate values at the start and end of the project will be entered.
- The kilometre (KM), elevation (KOT), vertical curve radius (R) and vertical curve length (L) of the vertical curve section shall be shown.
- A combination of vertical and horizontal curves shall be provided.
- The vertical alignment must be determined in such a way as to ensure the railway is as economical and safe as possible.
- When determining the vertical alignment, as with horizontal curves, the impact on all engineering aspects of the railway will be taken into account, and compliance with railway standards will be ensured. (Snow, frost, maintenance, aesthetics, class, ground movements, retaining structures, topography, geometric standards, safety, etc.)
- In calculations of vertical alignment gradients, the gradient shall be expressed in per mille. Gradients shall be rounded to two decimal places. Care shall be taken to ensure that the kilometre Figure s are whole numbers.
- When determining the vertical alignment, cross-sections and engineering structures shall be assessed together, and the conditions of the engineering structures shall also be taken into account in the cross-sections.
- Hydraulic structures, underpasses and overpasses, bridges and tunnels, retaining and shoring walls, and other geotechnical measures shall be shown on the profiles using appropriate symbols and notation.
- Profiles shall be prepared with the following information in the lower section, in order: Kilometre, Track top level, Ground level, Horizontal Geometry, Vertical Geometry and Deviation band.
- If the profiles do not fit within the allocated width on the sheets, an elevation transfer line shall be drawn.

1.6. HYDRAULIC AND HYDROLOGICAL STUDIES

To ensure that the natural course and flow of watercourses, streams and rivers, whose course and flow are interrupted by the railway structure to be constructed, continue appropriately; to collect, convey, and to discharge it, the necessary studies to determine the types and flow rates of the required hydraulic structures, diversions and other elements will be carried out. An IDF analysis will be performed for the hydraulic studies.

The Contractor shall also undertake an alignment-dedicated hydrogeological study covering the principal aquifer types, groundwater flow regime, and hydrogeological character of the main geological formations present along the detailed design alignment. This study shall be submitted to the Engineer for approval prior to commencing detailed design.

The points to be considered during the execution of hydraulic and hydrogeological studies are listed below;

- Based on the horizontal alignment, catchments will be identified on 1:25,000 and 1:5,000 scale maps and hydrological calculations will be performed. Flow distances, flow elevations, culvert kilometres and catchment areas will be marked on the catchment plan. Rainfall catchment plans will be prepared in colour.
- In flood discharge calculations, the Rational Method will be used for catchments with areas between 0 and 1 km².
- In flood discharge calculations, for catchments with areas between 1 and 10 km², the higher of the flood discharge values obtained from the Mochus and Synthetic Calculation Methods will be used.
- In flood discharge calculations, the Synthetic Method shall be used for catchments with areas exceeding 10 km².
- The rainfall values to be used in discharge calculations shall be taken from the most recent rainfall measurements.
- In the calculation of discharge for very large catchments and watercourses, direct flood discharge measurements carried out by the DSİ and other institutions shall be taken as the basis.
- The topography of the construction site, the spans and heights of existing bridges, their performance during past floods, and the highest water levels to be determined in the riverbed shall be taken as the basis.
- The hydraulic dimensions of the hydraulic structures will be determined for use in the studies to establish the project's vertical alignment.
- Dimensioning will be carried out based on the flood level, critical velocity, normal velocity, critical depth and normal depth.
- The calculations will take into account the base flows in the river channel and future sediment transport.
- Should there be any changes to the implementation projects, the hydraulic and hydrogeological studies will be revised.

Following the hydraulic and hydrological studies, a report will be prepared, and approval from the DSİ will be obtained for the prepared reports.

The reports and their contents shall be prepared in accordance with the principles set out below;

- The route; a presentation of all structures plotted on a 1:25,000 or 1:5,000 scale map, along with the catchment areas and defined riverbeds

- Copies of the hydraulic and hydrological calculations
- A list specifying the types of all structures in order of kilometre

The following points must be taken into account in the hydraulic calculations;

- At-grade (Embankments) and Fill Sections (Urban Areas)
  The greater of the water level calculated for 100-year flood discharge plus a minimum freeboard of 1.5 m. from the embankment height or 500-year flood discharge shall not exceed the embankment height. 1,000-year flood discharge shall not exceed the embankment height in case of exposed population and potential economic losses.

- At-grade (Embankments) and Fill Sections (Rural Areas)

  The greater of the water level calculated for 100-year flood discharge plus a minimum freeboard of 1.5 m. from the embankment height or 500-year flood discharge shall not exceed the embankment height.

- Bridge within settlement areas (Urban Areas)

  The water level corresponding to 500-year flood discharge plus a minimum freeboard of 1.5 m. 1,000-year flood discharge plus a minimum freeboard of 1.5 m. shall be used in case of exposed population and potential economic losses.

- Bridge outside settlement areas (Rural Areas)

  The water level corresponding to 500-year flood discharge plus a minimum freeboard of 1.5 m.

- Culvert within settlement areas (Urban Areas)

  The greater of the water level calculated for 100-year flood discharge plus a minimum freeboard of 1.5 m. or 500-year flood discharge. 1,000-year flood discharge shall be used in case of exposed population and potential economic losses.

- Culvert outside settlement areas (Rural Areas)

  The greater of the water level calculated for 100-year flood discharge plus a minimum freeboard of 1.5 m. or 500-year flood discharge.

- Traction substations

  To be located outside DSI-defined flood zones based on the 500-year return period.

- Station entrance thresholds and underground access points

  To be designed with raised sills and surface drainage channels based on the 500-year return period, and dedicated sump pumps with backup power provided at the lowest underground level against inundation.

- Embankment and cut slope stability

  Proper surface protection, toe support, and improved subsurface drainage to be implemented at susceptible embankment and cut slope sections.

- Culverts

  Inlet–outlet erosion protection, lined drainage channels, and toe drainage to be provided to prevent water ponding and embankment softening.

All work carried out shall comply with DSI standards and shall be approved by the DSI.

1.7. DRAINAGE STUDIES

To ensure that the natural course and flow of watercourses, streams and rivers, whose course and flow are interrupted by the railway structure to be constructed, continue appropriately; to collect, convey, and to discharge it, the necessary types of engineering structures, open and closed channels, collectors, head and toe ditches, drop channels, culverts, diversions and other elements will be determined, and their dimensions, locations, layouts and details will be designed for hydraulic purposes.

The following data will be used to carry out drainage projects:

- Flow rates determined as a result of hydraulic and hydrological studies
- Determination of the flow rate generated by rainwater falling on the railway surface and studies aimed at the appropriate collection and drainage of this water
- Locations and positions of surface water conveyance, drainage and discharge systems, including hydrological culverts, bridges, diversions, bypasses and channels

Using the data provided above, the final positioning, sizing and detailing of the drainage system components will be carried out.

The following considerations will be taken into account in the drainage design work:

- Where possible, direct energy equations and open channel flow velocity and capacity formulas will be preferred over abacuses.
- Rainfall values used in flow calculations shall be based on the latest rainfall measurements.
- Rainfall values will be taken from the Rainfall-Intensity-Frequency curves prepared by the General Directorate of Meteorology.
- The assumptions made in the use of the formulas and the values selected for the parameters shall be clearly stated in the design report.
- Pressurised flow shall not be permitted in collectors and similar channels running through long sections.
- Measures shall be taken to ensure that scour rates are not reached in flow channels, railway side ditches and at the outlets of culverts.

- It shall be ensured that any swelling permitted at culvert inlets remains within the limits specified in the specifications and/or by the client.
- Hydraulic jumps that may occur at culvert outlets and the resulting risk of scouring shall be thoroughly investigated, and necessary measures shall be designed.
- In cuttings and embankments, the free flow of rainwater down slopes shall be minimised. Sloping shall be considered as a method to achieve this objective.
- Rainwater in cuttings and embankments will be conveyed in the longitudinal direction over sufficient lengths— via embankment and cutting drainage ditches, embankment edge asphalt ditches, and embankment base slope ditches, and channelled to culverts, natural watercourses, or discharge points or structures via drop channels, chutes, and discharge channels.
- Rainwater and flood flows transported along the natural drainage lines of the catchments will be directed directly to hydraulic culverts.
- In sections with high and deep cuts, watercourses will be diverted and transported to the nearest discharge point via chutes and drop channels.
- To prevent water from flowing freely down slopes in embankment ditches and fill areas, drop channels will be installed at regular intervals.
- All types of water course and stream diversion and channelling structures shall be designed with careful consideration of the effects of sedimentation, scouring and bank erosion, taking into account appropriate conveyance capacity and the necessary strength and protection characteristics, and shall be designed in cross-section types.
- When establishing the drainage system, the design will be carried out on a sloped digital model during the initial or appropriate stages to ensure that flows can be properly monitored and that elevations, gradients, and other topographical and geometric features can be effectively and accurately interpreted and assessed.
- Underground drainage shall be implemented in cut sections.
- For the design of drainage systems, the maximum return periods specified in Section 1.6 shall be considered for each structure.

The requirements to be adhered to when presenting drainage project documents and reports are listed below;

- Drainage structures and elements, accompanied by explanatory notes, shall be added to the project drawings with representations corresponding to their actual dimensions and locations.
- Representations and elements not directly related to the drainage design shall be removed from the drawings.
- Profile representations of piped drainage systems shall be provided.
- To ensure the drainage system is presented and can be traced appropriately, including flow directions, the profile section of the drawings, contour lines characterising the terrain, and other cartographic information shall be included on the project drawings.

- The dimensions of structures and elements within the drainage system, hydraulic design and details, and other necessary details required to fully define the intended function of the relevant element shall be provided.
- These elements within the drainage system shall be depicted on separate sheets with sufficient detail, including plans, sections and/or descriptions, in a sufficient number of scales (1/500, 1/250, 1/100, 1/25, 1/10 or the appropriate scale for each) to comprehensively cover all locations of use.
- For each component of the drainage system presented on the main sheets, the corresponding type from those mentioned above shall be indicated by at least an appropriate symbol and, where possible, its dimensions, capacity or other key characteristics shall be provided.
- Drainage reports shall specify the description of the drainage system created and the considerations and principles taken into account in the design.
- The hydraulic sizing of the hydraulic structures and components comprising the drainage system, along with all other hydraulic calculations and verifications, shall be included in the report.
- A list of drainage system components, showing the locations, dimensions, and, where applicable, capacities or similar characteristic parameters of the structures and hydraulic elements comprising the drainage system, shall be included in the reports.

1.8. STATIONS

The most important considerations in station design are ensuring the comfortable and safe movement of passengers during normal operating periods and the evacuation of passengers through effective crowd management in emergency situations. In the design and sizing of stations, a balance must be struck between capacity and cost.

A well-designed station must incorporate the following features:

- Effective integration with the surrounding area, nearby buildings and other modes of transport
- A spatial design that is simple and easy to navigate, facilitating passenger movement within the station and minimising walking distances and times
- Circulation areas free from unnecessary and confusing turns, conflicting pedestrian flows, dead-ends and bottlenecks
- Safe and comfortable access for passengers of all groups between the surface exit and the train
- Barrier-free, accessible design for all users
- Clear, easily recognisable passenger area designs with short walking routes
- Sufficient escape routes for emergency evacuation measures, prepared for crowding and service disruptions,
- Technical areas necessary/sufficient for line operations

- Controlled and safe access between technical areas, control rooms and passenger areas
- Spaces that do not hinder camera surveillance for station security

1.8.1. Station Passenger Volumes

The spatial design of the station shall be based on the volumes stated in Technical Evaluation Report.

1.8.2. Passenger Flow and Evacuation

Passenger demand scenarios for the station will be taken into account. Peak hour, emergency and failure scenarios will be analysed. Analyses will include horizontal and vertical circulation (stairs, escalators, lifts) capacity analysis, platform occupancy analysis, and evacuation simulations.

Evacuation times will comply with national and international standards. No congestion will occur on escape routes. Uninterrupted access for people with disabilities will be ensured. The Table below summarises the limit values for the main elements.

The limits provided shall be considered as the minimum criteria that must be met and shall be applied appropriately in accordance with current regulations.

Parameter	**Criterion**	**Analysis Method**	**Acceptance Criterion**
Discharge time	≤ 4 min (platform) ≤ 6 min (station without fire resistant safe refuge area)	Simulation (Pathfinder, etc.)	To be provided
Walking speed	1.2 m/s (average)	Standard acceptance	To be used
Max. density	≤ 4 people per square metre	Passenger flow analysis	Not to be exceeded
Staircase capacity	≥ 35 people/min/m	Calculation	To be provided
Escalator	≥ 90 people/min	Calculation	To be provided

1.8.3. Station Entrance and Exit Structures

Station entrance structures must be determined by assessing the immediate surroundings of the station within a radius of at least 500m. Important destinations in the vicinity of the station,

such as hospitals, schools and cultural centres, and pedestrian access routes from these points must be taken into account.

The aim should be to ensure integration with public transport modes via the shortest route. Space must be allocated near station entrance structures for bicycle and scooter parking areas and rental units. When making these arrangements, care must be taken not to disrupt existing pavement usage.

When planning the layout of station entrance structures, measures will be taken to reduce expropriation and construction costs, affect as few plots as possible, and carry out pavement and road arrangements for passenger drop-off points and taxi bays. Station entrance and exit tunnels may be designed by evaluating safe and economical alternatives, taking ground conditions into account. Taking into account potential issues that may arise during the construction phase, revisions to the levels and routes of the entrance and exit structures are possible, subject to the approval of the authority and the consultant, provided that this does not increase costs. -guided surfaces or warning surfaces shall be designed for the marking of pedestrian pavements and crossings in front of the station , and these designs shall comply with TS ISO 23599 and TS 9111 standards.

Floor coverings used at station entrances and on staircases must be slip-resistant. Rainwater drainage channels must be installed at both the top and bottom of street entrance staircases, extending the full width of the stairs and escalators. Station entrances, lifts, emergency exit structures and technical shafts must be adjusted according to the region’s flood level; should a level difference arise between the street level and the station entrance, ramps and stairs must be provided, and queuing distances must be taken into account in the design of station entrances.

Station entrances may be covered for reasons of security, adverse weather conditions, frequent equipment breakdowns, etc.; this matter will be clarified by an administrative decision on a project-by-project basis. In areas where canopies are to be installed at station entrances, and where efficiency in terms of energy production has been determined through analyses, PV solar panels may be used, subject to an administrative decision.

Where station entrances are covered by a canopy, roller shutter doors must be installed at street level; where no canopy is installed, roller shutter doors must be installed in the area where the stairs descend. A passenger information system must be installed in the station entrance area (preferably on the entrance canopy).

Where there is no overhead canopy at station entrances, the stairwell area must be fitted with a railing comprising a parapet of at least 70 cm in height and a 304-grade stainless steel railing on top, with a minimum height of 120 cm; horizontal rails must not be used (to prevent children from climbing).

For the parapets of station entrance structures, materials that are easy to clean, polished, stain-resistant, have low water absorption and high durability should be selected; timber should not be used.

At entrances close to the carriageway, where there is a risk of vehicles leaving the road and entering the station, the parapet may be raised to mitigate these risks.

To ensure the safety, passenger comfort and security of station entrances, they must be adequately lit. Cameras should be positioned to monitor the station entrance staircases and street-level lifts, and at least one of these cameras should be designed as a pan-tilt-zoom (PTZ) camera.

1.8.4. Station Platforms

Platform types of stations are indicated in the reference design (conceptual drawings) which is a part of the tender documentation.

In the event of any changes in passenger volumes or the emergence of new requirements communicated by AYGM that may affect platform dimensions, the Contractor shall recalculate the platform dimensions accordingly as described below.

Platform dimensions, to be determined based on normal and emergency passenger loads, shall be calculated in accordance with TS 12127 and TS 12186.

For the permitted passenger density on platforms during normal operating periods, the values specified in TS 12127 and TS 12186 standards shall be used as a basis. These values are 0,35m² – 0,50m² per person for above-ground stations and 0,50m² – 0,75m² per person for underground stations.

As the TS Standards do not specify values regarding the area to be allocated per person or passenger load calculations for emergency situations in stations, the values specified in NFPA130 and NFPA101 shall be used as a basis for emergency passenger loads.

When determining the passenger capacity of platforms, the ‘net platform area’ calculation shall exclude the 0,50 m safety zone along the platform edge and the accumulation areas in front of the stairs. Where platforms are located within a tunnel, due to passengers walking away from the curved tunnel walls as a result of the head rescue distance, a 30 cm area on the curved wall side shall also not be included in the net platform area.

Platform length will be determined according to the length of the train formation in the project’s operational scenario and technical requirements; the train length plus a 5-metre buffer will provide the net platform length. Platform width will be determined based on the passenger load during peak hours—including passengers alighting, boarding, and waiting for the next train on

another line—as well as the functional circulation of passengers on the platform and in surrounding facilities, and the platform's capacity. Although minimum platform width values are specified in TS 12127 and TS 12186 standards, platforms are designed with varying widths depending on passenger volume and emergency conditions.

The net platform length (the area where the train will stop) is determined according to the length of the train formation in the project's operational scenario, whilst the total platform length is determined according to technical requirements such as access to technical areas on the platform and access to emergency escape staircases. The terms "platform head" and "platform tail" denote the start and end of the net platform area.

A 0,50 m wide safety edge strip compliant with TS 12692 shall be provided along the track-side edges of the platforms; between the safety strip surfacing and the floor surfacing, a warning surface (HYYİ) shall be provided at stations without PSDS (Platform Screeen Door System), and a 10 cm wide warning strip shall be installed at stations with PSDS. Structures providing vertical circulation, such as stairs and lifts, shall be excluded from the net width. On lines where PSDS is used, whilst a 0,50 m safety edge strip is not required, as passengers will stand at a distance from the PSDS due to the wall effect, platform capacity calculations shall be made by deducting 0,50 m from the platform width. Sufficient width must be provided to ensure passengers can circulate without becoming entangled with passengers waiting in clusters in front of the PSDS.

The platform floor level shall be at the same level as the vehicle floor to facilitate passenger boarding and ensure accessibility for people with disabilities.

Suspended ceiling designs should preferably be designed at a height of 3.5m above floor level. However, where a height of 3.5m cannot be achieved due to infrastructure, tunnel geometry, etc., the suspended ceiling height may be designed to be at least 3m, subject to the provisions of TS 12127. The lower edge of any equipment and signage to be mounted on the suspended ceiling must be at a height of 2,5 m above the floor.

A gap of 5–8 cm may remain between the platform edge and the train; the platform edge shall be parallel to the track, and the distance between the platform edge and the track centreline shall be calculated according to the width of the selected rolling stock. On curves, the platform edge shall be at the track's tangent. General principles for passenger circulation on the platform:

- A safety refuge niche, 60 cm wide and 90 cm high, shall be provided beneath the platform flooring at the platform edge,
- Vertical circulation elements shall ensure a balanced and even distribution of passengers on the platform,
- Care must be taken to ensure that passenger waiting areas at the platform edge do not intersect with stairwell queuing zones,

- Where possible, right-hand passageways shall be encouraged,
- Crossing flows will be avoided,
- Dead-end corridors shall be avoided,
- Connecting tunnels that do not lead to any exit shall be avoided,
- Platform layout and signage shall enable passengers to know their location and easily find their destination,
- Passenger flow plan shall ensure that elderly and disabled passengers can easily reach their destinations,
- The maximum escape distances and unit widths specified in the regulations on fire protection for buildings shall be taken into account. Escape distances shall be 15 metres where there is no sprinkler system and 25 metres where there is one.

Platform end doors shall be installed at the ends of platforms to prevent unauthorised passenger access to technical areas. To ensure that passenger evacuation from the tunnel can be carried out easily and quickly in an emergency, platform end doors must open from the track towards the platform. On lines where PSDS is to be implemented, platform end doors must be integrated into the PSDS system. Doors leading from the platform end to technical areas must be fitted with a card access system; when the door is opened, information must be displayed on the station control room's SCADA screen.

There must be no obstacles (walls, furniture, panels, columns, etc.) within a 2.5 m depth from the platform edge, along the entire length of the platform. Seating elements installed on the platforms must not be placed within 5 m of points such as platform exits, connecting tunnels, lifts, and emergency exits.

1.8.5. Acoustic

Stations and track structures must be designed to ensure that noise propagation caused by vibrations from passing trains remains within the levels specified in the standards. The intelligibility of announcements within the station is of great importance. Stations are acoustically problematic spaces due to the predominantly reflective nature of the cladding materials used. Consequently, station interior designs must ensure acoustic comfort conditions so that people can communicate easily and excessive noise is prevented. The public address system must ensure that announcements are easily audible and intelligible. Furthermore, acoustic comfort conditions must also be provided for operational staff outside passenger areas.

When designing station interiors, acoustic comfort conditions will be ensured, and the designs will comply with TS 12127 and TS 12186 standards, relevant building acoustics standards, and the Regulation on the Assessment and Management of Environmental Noise.

To ensure acoustic comfort conditions, sound-absorbing materials must be used on the walls and ceilings in platform and ticket hall areas. The use of sound-absorbing materials must control noise generated by trains and the reverberation of this noise within the station.

The creation of a suitable environment for public address systems within the station area can be ensured by ensuring that the speech intelligibility parameter (STI) values are appropriate and that the A-weighted sound pressure level (SPLA) of announcements is at a sufficient level. For this reason, the control of the reverberation time ( ), a parameter that directly affects these parameters, is an important parameter that must be evaluated within the scope of the station's acoustic design.

Acoustic measures must also be implemented in technical areas. Measures must be taken to address noise generated by ventilation systems, escalators, lifts and other mechanical systems. In rooms housing noisy equipment, vibration insulation will be installed between mounting feet or brackets. Sound transmission through openings and gaps must be controlled.

In addition to acoustic measures within station interiors, environmental noise analyses must be conducted for residential buildings, hospitals, schools and similar structures located near the railway line. The necessary measures to ensure compliance with the required standards will be implemented in the project. The noise levels generated by rail systems and the criteria for noise prevention are set out in the Regulation on the Assessment and Management of Environmental Noise.

Room acoustics and environmental noise analyses will be carried out using computer simulations; the acoustic conditions will be assessed, and the necessary measures will be taken to ensure compliance with the threshold values required by standards and regulations, whilst also ensuring comfort conditions.

The evaluation of the project output data obtained through acoustic modelling and calculations shall be carried out in accordance with the "Regulation on the Protection of Buildings Against Noise" published by the Republic of Türkiye Ministry of Environment, Urbanization and Climate Change in the Official Gazette dated 31 May 2017 and numbered 30082.

Within the scope of the relevant regulation, Annex 6 Table 6.1 defines the permissible reverberation times according to building function and space type. However, the volumes used within the scope of the Project are not directly covered by the building functions defined in Table 6.1.

For spaces where the design criteria may vary depending on the specific characteristics of the project, Table 6.1 states that: "Appropriate values for such spaces shall be determined by the acoustic specialist according to the characteristics of the structure."

Accordingly, as railway transit station spaces possess unique acoustic characteristics and operational requirements, a dedicated reverberation time criteria set shall be established for the Project.

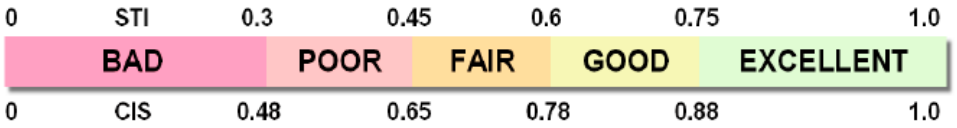
The maximum reverberation time criterion, determined as the average value at 250 Hz, 500 Hz, 1000 Hz and 2000 Hz octave bands, shall be 2.0 seconds. Although the upper permissible limit shall be an average of 2.0 seconds, the design target for the Project shall aim for average reverberation times in the range of 1.6–1.7 seconds.

The determination of these criteria shall be based on spaces identified in Table 6.1 that are acoustically most comparable to metro station environments; and relevant national and international technical literature and previously completed studies.

In addition to the applicable regulatory limits, the STI (Speech Transmission Index) parameter shall also be evaluated in order to ensure the intelligibility of announcements and public address systems within railway transit stations.

The STI parameter is an indicator of speech intelligibility and shall range between 0 and 1, where:

- 0 indicates unintelligible speech; and
- 1 indicates perfectly intelligible speech.



Speech Transmission Index (STI) Evaluation Scale

The primary reason for maintaining low reverberation times within railway transit stations shall be to improve the STI parameter. Since station structures are technically complex environments where the intelligibility of announcements and emergency messages is of critical importance, speech intelligibility shall be treated as a key design objective.

Accordingly, the STI parameter within passenger areas under normal operating conditions shall achieve a minimum rating corresponding to the “Good” category, i.e.: STI > 0.60

It is acknowledged that TVF (Tunnel Ventilation Fan) emergency operation scenarios may generate signifisuperelevation noise levels within tunnel environments. Therefore, the TVF operational condition shall also be modelled as an emergency scenario.

Under TVF operation scenarios, the background noise level within passenger areas may increase substantially, which may adversely affect the STI parameter. However, depending on the detailed design of the electro-acoustic system, the STI performance may not be affected proportionally by the increased noise level.

Accordingly, under TVF emergency operation scenarios, the STI parameter within passenger-accessible areas shall achieve at minimum the lower limit of the “Fair” category, i.e.: STI > 0.45.

1.8.6. Hydraulic and Drainage Design

Station water inlets will be designed taking into account groundwater and rainwater. Pump capacity calculations will be carried out. There will be no risk of flooding. Areas housing critical equipment will be protected. IDF analyses will be conducted for pipelines and stations to determine the required flow rates.

The Table below summarises the limit values for the main parameters. The specified limits shall be considered as the minimum criteria to be met and shall be applied appropriately in accordance with current regulations.

Parameter	Criterion	Analysis Method	Acceptance Criterion
Rainfall return period	DSİ - IDF Analysis	Hydraulic modelling	To be provided
Pump capacity	Q ≥ 1.5 × peak flow	Calculation	To be provided
Risk of water ingress	0	Analysis	To be provided

1.8.7. Acoustic and Public Address System

The station’s interior acoustic design will be carried out. Reflections, reverberation time and background noise will be controlled. Uniform sound distribution will be ensured throughout all areas. Speech intelligibility will be at an acceptable level. Emergency announcements will be clear and intelligible.

The Table below summarises the limit values for the main parameters. The specified limits shall be considered as the minimum criteria to be met and shall be applied appropriately in accordance with current regulations.

Parameter	Criterion	Analysis Method	Acceptance Criterion
STI (Speech Transmission Index)	≥ 0.5 (good)	Acoustic modelling	To be provided
Reverberation time (RT60)	≤ 1.5 s	Simulation	To be provided
Sound level	65–75 dBA	Measurement	To be provided

1.8.8. CCTV System Coverage and Image Quality

All critical areas of the station (platforms, entrances/exits, turnstiles, technical areas, etc.) will be monitored by cameras. No blind spots will be left. Image resolution will be at a level sufficient for facial recognition and incident analysis.

The Table below summarises the limit values for the main parameters. The specified limits shall be considered as the minimum criteria to be met and shall be applied appropriately in accordance with current regulations.

Parameter	Criterion	Analysis Method	Acceptance Criterion
Camera coverage	100% (no blind spots)	Deployment analysis	To be provided
Resolution	≥ 1080p	Technical selection	To be provided
Recognition range	≥ 15 m (face)	Vision analysis	To be provided

1.8.9. Additional Measures for People with Disabilities

This group includes those with limited mobility, wheelchair users, people with hearing or visual impairments, those with luggage or pushchairs, and the elderly. In the design of stations and facilities for this group, compliance with the criteria set out in the TS 12460, TS 12692, TS 12574, TS 9111 and TS ISO 23599 standards, as well as the Accessibility Guide published by the Ministry of Family, Labour and Social Services, shall be ensured.

At stations, all necessary measures must be taken to ensure that people with disabilities can move safely between street level and the platform without requiring assistance. Lifts must be designed with at least two units, taking into account potential breakdowns or maintenance requirements.

In accordance with TS 9111, tactile symbols and letters must be applied to handrails, doors, lifts, raised-relief maps or floor plans at stations.

Tactile signs, written in Braille (for the blind), must be used as information and assistance tools for the use of areas required by visually impaired passengers. If a sign is to be placed next to a control panel, it must be easily accessible and positioned at a height of 120–160 cm above the floor to meet the needs of both a standing person and someone in a wheelchair. Tactile signs must feature raised text or symbols of a size that ensures the information is easily understood.

Signs indicating the type and gender of the toilet should be placed next to passenger toilet doors. Tactile signs should be located on the wall next to the door handle, at a height of 120–160 cm from the floor. Inside the toilets, they may be placed on the door itself.

In the event of an emergency, operational staff and fire crews will assist with the evacuation of passengers with reduced mobility; for this purpose, at least one lift must be designed to operate in an emergency.

A tactile map for disabled access, featuring Braille and raised text, should be installed near the lift at street level in stations, or in a suitable area on the floor where the lift stops. Only essential information should be included on the tactile map or floor plan.

Maps and floor plans must not be placed on a horizontal surface; they must be mounted at an angle of between 20° and 30° to facilitate reading. The lighting on the surface of the map must not cause glare and must be between 350 and 450 lux. The legend must be aligned to the left and positioned at the bottom of the map.

One accessible toilet shall be provided at each station. Users with reduced mobility must be able to use the accessible toilet within the station as easily as other passengers.

To ensure that visually impaired or partially sighted passengers can easily identify them, all door-opening fittings must be in a colour that contrasts with the door leaf. The door lock must be equipped with a remotely operated opening mechanism to allow intervention in emergencies.

Seating should be positioned near accessible lifts to assist passengers with reduced mobility and should be situated in such a way that it does not obstruct visually impaired passengers or those with visual impairments, whilst allowing visually impaired passengers using a cane to locate them.

1.9. VIBRATION and NOISE

Vibration and noise levels that may occur along the station and track will be analysed. The effects of the values obtained from the analysis on structures, the environment and sensitive equipment will be assessed. Where vibration levels exceed acceptable limits in terms of human comfort and structural safety, vibration damping systems will be implemented. Noise levels within the station will be below the limits specified in current regulations.

The Table below summarises the limit values for the main parameters. The specified limits will be considered as the minimum criteria that must be met and will be applied appropriately in accordance with current regulations.

Parameter	Criterion	Analysis Method	Acceptance Criterion
Vibration (structure)	Max. 5 mm/s (PPV)	Dynamic analysis/field modelling	Not to be exceeded
Vibration (human comfort)	0,1 m/s² RMS	ISO 2631	Not to be exceeded
Noise (in-station)	≤ 65 dBA (typical) / ≤ 75 dBA (peak)	Acoustic modelling	To be provided
Noise (during announcements)	SNR ≥ 10 dB	Measurement/simulation	To be provided

1.10. FIRE LOAD and SMOKE CONTROL

A fire load calculation will be performed taking into account all combustible loads within the station (train, cables, equipment, architectural elements, etc.). The station will be analysed, including a scenario involving a burning train.

Smoke extraction systems (jet fans, axial fans, etc.) will be sized according to the scenario. Escape routes will be protected from the effects of smoke. During the evacuation period, temperature, visibility, and CO level values in the escape routes will remain within acceptable limits.

In the fire design, the final lining concrete inside the tunnel will be designed in accordance with TSI-SRT principles for main line tunnels and NFPA 130 principles for stations. But fire loads of passanger and freight train set will be determined according to TSI.

The Table below summarises the limit values for the main elements. The specified limits shall be considered as the minimum criteria that must be met and shall be applied appropriately in accordance with current regulations.

Parameter	Criterion	Analysis Method	Acceptance Criterion
Fire load	TSI	CFD / FDS simulation	Design to be carried out accordingly

Parameter	Criterion	Analysis Method	Acceptance Criterion
Temperature (escape route)	≤ 60°C	Fire scenario analysis	Not to be exceeded
Visibility	≥ 10 m	Smoke dispersion analysis	To be ensured
CO level	≤ 500 ppm	CFD analysis	Not to be exceeded
Smoke evacuation time	≤ 6 min	Simulation	To be provided

1.11. RADIO and COMMUNICATION COVERAGE

Uninterrupted radio communication will be provided within the stations and along the line. Coverage analysis will be carried out in tunnels and stations. Signal levels in critical areas will not fall below the minimum threshold value. Uninterrupted communication will be provided for emergency response teams.

The Table below summarises the limit values for the main parameters. The specified limits shall be considered as the minimum criteria to be met and shall be applied appropriately in accordance with current regulations.

Parameter	Criterion	Analysis Method	Acceptance Criterion
Signal level	≥ -85 dBm	RF simulation	To be provided
Coverage	100% of the station area	RF analysis	To be provided
Downtime	0 s (critical area)	Test	To be provided

1.12. POWER SUPPLY and CONTINUITY

The station’s power system will be designed with dual power supply. UPS and generator systems will be installed for critical systems. In the event of a power outage, critical systems (lighting, public address, signalling, etc.) will continue to operate. System availability targets will be met.

The Table below summarises the limit values for the main components. The specified limits shall be considered as the minimum criteria that must be met and shall be applied appropriately in accordance with current regulations.

Parameter	Criterion	Analysis Method	Acceptance Criterion
Supply	Dual (redundant)	System design	To be provided
UPS runtime	≥ 60 mins	Calculation	To be provided
Generator start-up	≤ 15 s	Test	To be provided
Availability	≥ 99.9%	RAMS analysis	To be provided

1.13. CLIMATE RESILIENCE

1.13.1. Purpose of Climate Resilience

The Project shall be designed to achieve an appropriate level of climate resilience throughout its full operational design life. Climate resilience shall be considered in the design of civil, structural, geotechnical, railway systems, electrical, mechanical and operational assets to ensure safe operation, service continuity and protection of railway infrastructure under future climate conditions.

1.13.2. Climate Hazards

Climate resilience assessments shall address, as a minimum, the potential impacts of extreme precipitation, flooding, extreme heat, drought, wildfire, wind, snow and ice, groundwater changes, erosion and climate-induced slope instability, taking into account the geographical characteristics of the Project.

1.13.3. Design Life

All climate projections, resilience assessments and adaptation measures adopted for the Project shall be based on the full operational design life of the relevant infrastructure and systems.

1.13.4. Climate Resilience Assessment

The D&B Contractor shall prepare a Climate Resilience Assessment demonstrating that the adopted design satisfies the climate resilience objectives defined in this Specification and remains suitable under the climate scenarios adopted for the Project.

1.13.5. Operational Continuity

Climate adaptation measures shall be selected to minimise disruption to railway operations and to maintain operational safety, availability and maintainability throughout the design life of the Project.

1.14. RAMS

RAMS analyses will be carried out for all systems. The targeted business continuity will be ensured. Maintenance times and failure rates will be at an acceptable level.

Parameter	Criterion	Analysis Method	Acceptance Criterion
Reliability (MTBF)	≥ 50,000 hours	RAMS analysis	To be provided
Mean Time to Repair (MTTR)	≤ 4 hours	Analysis	To be provided
Availability	≥ 99%	Account	To be provided

All performance criteria defined above will be verified through analyses during the design phase and confirmed by measurements during post-implementation testing and commissioning processes.

1.15. SYSTEM REDUNDANCY

System redundancy criteria will be defined by discipline as follows:

- Signalling Systems: Safety-critical equipment such as interlocking systems, axle counters, track circuits and signals shall be designed in accordance with the fail-safe principle and in a redundant architecture (e.g. dual-processor, hot-standby configuration). In double-track sections, each track shall be capable of independent operation, and a fault occurring on one track shall not affect the operation of the other track.
- Power Supply Systems: To ensure system continuity, at least two independent power sources (e.g. mains supply + backup power/generator/UPS) shall be provided. Automatic transfer systems that activate in the event of a power failure shall be installed.
- Telecommunications Systems: The critical communications infrastructure will be designed in a redundant topology (e.g. ring architecture) to eliminate single points of failure. Critical equipment will be installed in a redundant configuration.
- SCADA / Control Systems: Servers and control systems will be installed in a redundant (hot-standby) configuration, ensuring that the system's monitoring and control functions continue uninterrupted in the event of any failure.
- Infrastructure and Line (Overhead): Natural redundancy is provided in double-circuit line sections; to the extent permitted by the signalling system, limited two-way operation may be carried out via the other circuit in the event of one circuit being taken out of service.

The Technical Specifications for Remote Control Systems, the Technical Specifications for Substations, and the Technical Specifications for Signalling, Telecommunications and Support Systems define the necessary conditions for ensuring system continuity and the principles regarding redundancy.

1.16. ASSESSMENT OF SITE-SPECIFIC SEISMIC CONDITIONS

Site-specific seismic analyses will For the definition of seismic hazard, a probabilistic seismic hazard assessment (PSHA) methodology shall be adopted for the Site-Specific Seismic Study.

The PSHA shall consider all relevant potential earthquake scenarios that may affect the Project area and shall evaluate the exceedance probabilities corresponding to ground motion parameters, including but not limited to peak ground acceleration (PGA) and spectral acceleration values for both reference rock conditions and site-specific ground conditions.

The PSHA shall include, as a minimum:

- identification and characterization of seismic source zones;
- evaluation of regional tectonic structure, seismicity and active fault data;
- definition of earthquake occurrence characteristics for each seismic source;
- selection and justification of appropriate ground motion prediction equations (GMPEs);
- probabilistic evaluation of seismic hazard levels for the Project area; and
- preparation of site-specific seismic hazard parameters for use in structural and geotechnical design.

The seismic hazard assessment shall be performed using internationally accepted methodologies and engineering practices consistent with recognized references and standards applicable to major railway and infrastructure projects.be carried out as part of the project.

1.17. CLIMATE RESILIENCE & UPLIFT FACTORS

Climate change shall be systematically incorporated into the design of the Project to ensure that the railway infrastructure, systems and associated facilities remain safe, reliable and operational throughout their intended design life under future climatic conditions.

The D&B Contractor shall undertake project-specific climate resilience assessments using recognised climate projections, regional climate datasets and applicable national requirements.

The selection of climate scenarios shall be appropriate to the type of climate hazard being assessed. The temporal horizon of all climate projections adopted for design shall be consistent with the full operational design life of the Project.

For hydraulic and flood-related assessments, the design shall be based on the SSP2-4.5 scenario and verified under the SSP5-8.5 scenario to demonstrate resilience under upper-bound climate conditions.

For assessments related to extreme heat, drought and wildfire, the design shall be based on the SSP5-8.5 scenario.

Where official high-resolution SSP climate projections for Türkiye are unavailable, the Contractor shall establish the design basis through comparison of recognised regional SSP

datasets and the latest available national climate projections, adopting the more onerous values relevant to the Project.

Climate uplift factors shall be derived from project-specific, location-specific and hazard-specific climate assessments rather than the application of fixed default values.

The requirements of this Section define the methodology to be adopted for climate scenario selection, climate projection sources, climate uplift factors, hydraulic design criteria and climate resilience verification throughout the detailed design process.

1.17.1. Climate Scenario Selection

For hydraulic and flood-related assessments, the D&B Contractor shall adopt climate projections based on the SSP2-4.5 scenario for design purposes and shall verify the adequacy of the design under the SSP5-8.5 scenario as a climate resilience stress test.

For assessments related to extreme heat, drought and wildfire, the detailed design shall be based on the SSP5-8.5 climate scenario.

1.17.2. Climate Projection Sources

The D&B Contractor shall establish the climate design basis using recognised, scientifically validated and up-to-date climate projection datasets appropriate for the Project.

Where official high-resolution SSP-based climate projections for Türkiye are unavailable, the Contractor shall compare the latest available EURO-CORDEX or CORDEX-CORE climate projections developed under the WCRP CORDEX programme for the SSP2-4.5 and SSP5-8.5 scenarios with the latest national climate projections prepared by the General Directorate of Meteorology (MGM), including the 2015 RCP-based projections where applicable.

The EURO-CORDEX dataset, having a spatial resolution of approximately 0.11° (approximately 12.5 km), shall be considered suitable for regional infrastructure planning unless more detailed and technically justified datasets are available.

The design values shall be derived from the comparison of these datasets, and the more stringent values relevant to the Project location, climate hazard and design life shall be adopted, subject to the approval of the Engineer.

Any alternative climate datasets proposed by the Contractor shall be supported by appropriate technical justification and shall demonstrate an equivalent or higher level of scientific reliability, locational resolution and relevance to the Project.

1.17.3. Climate Uplift Factors

Climate uplift factors shall be established separately for each climate hazard and shall be derived from project-specific, location-specific and hazard-specific climate assessments.

The D&B Contractor shall determine the required climate uplift factors by comparing historical climate observations with future climate projections obtained from the approved climate datasets specified in Clause 1.17.2. The adopted uplift factors shall be based on the projected changes relevant to the Project location, asset type, design life and applicable climate scenario.

The methodology shall consider, as applicable, projected changes in:

- maximum and minimum air temperatures;
- precipitation intensity and duration;
- design rainfall and Intensity-Duration-Frequency (IDF) relationships;
- peak runoff and design discharge;
- flood levels;
- groundwater conditions;
- drought severity and duration;
- wildfire hazard;
- wind loading;
- snow and ice loading;
- any other climate parameter demonstrated to influence the performance or safety of the Project.

Where more than one recognised climate projection dataset is available, the D&B Contractor shall compare the projected values and adopt the most stringent values appropriate for the relevant design application, unless otherwise approved by the Engineer.

The proposed climate uplift factors, together with the methodology, assumptions, datasets, statistical analyses and engineering justification used for their derivation, shall be submitted to the Engineer as part of the Climate Resilience Assessment and Design Criteria Report for review and approval prior to commencement of the detailed design.

Climate uplift factors shall not be applied uniformly across the Project. Uplift factors shall be established individually for each climate hazard, engineering discipline and geographical section where climate projections indicate materially different future conditions.

1.17.4. Climate Adaptation Measures

In addition to the general climate resilience requirements specified herein, the D&B Contractor shall incorporate appropriate climate adaptation measures into the detailed design. As a minimum, the following requirements shall be considered where applicable:

- Extreme Heat

  HVAC systems serving station buildings, underground stations, technical rooms and other critical equipment spaces shall be designed using projected future ambient temperatures established in accordance with Clause 1.17.

- Wildfire

  Corridor-level wildfire exposure screening shall be undertaken to identify open sections, tunnel portals, bridge approaches and technical compounds exposed to wildfire risk. Appropriate mitigation measures, including firebreaks, fire-resistant landscaping, vegetation management and fire-water supply systems, shall be incorporated where required by the Climate Resilience Assessment.

- Drought

  The assessment of long-term geotechnical behaviour shall consider projected reductions in groundwater recharge, long-term drying trends and their potential effects on soil stability, embankment performance, cut slopes and underground structures. Where required, appropriate mitigation measures, including ground improvement, soil stabilisation, geosynthetics, drainage enhancement and vegetation measures, shall be incorporated into the design.

Additional climate adaptation measures identified through the project-specific Climate Resilience Assessment shall be incorporated into the detailed design as necessary to ensure the required level of climate resilience throughout the operational design life of the Project.

1.18. SPECIAL SYSTEMS

The requirements for the use of special systems on the railway line will be assessed during the design phase and implemented in accordance with the principles set out below.

General principles regarding special systems:

- Special systems to be integrated into the railway infrastructure and superstructure shall be designed with a focus on operational safety, system continuity and passenger comfort.
- All special systems shall comply with relevant railway standards, national legislation and the operator’s technical requirements.
- The design of the systems shall take into account track geometry, operating speeds, traffic density and environmental conditions.
- All special systems shall operate in a compatible and integrated manner with power supply, signalling and central control systems.

- Risks associated with data latency between systems, single-point failures and communication interruptions will be analysed during the design phase, and the necessary redundancy will be provided.
- Maintenance, testing and calibration requirements will be defined in the design in such a way as not to disrupt operations.
- The performance of the special systems will be verified through simulations and scenario analyses.
- The systems will be designed and certified to comply with relevant national and international railway standards and technical specifications.
- The principles regarding special systems that may be used on the line are set out below;

1.18.1. Early Earthquake Warning System

- The early earthquake warning system shall be designed to operate fully integrated with railway signalling and train control systems.
- The system will automatically trigger scenarios for reducing train speed or controlled stopping, taking into account earthquake detection, data transmission and decision-making times.
- Warning threshold values will be determined based on regional seismic hazard analyses and critical structures along the line (bridges, viaducts, tunnels, etc.).
- The system will be designed to be redundant and in accordance with the fail-safe principle against false alarms, communication interruptions and component failures.

1.18.2. Climate-Based Limited Operation System

- Meteorological and environmental parameters affecting the line (temperature, wind, precipitation, icing, etc.) will be analysed during the design phase.
- Operational threshold values will be defined for parameters such as rail temperature, wind speed and rainfall intensity.
- Speed restrictions, operational limitations and temporary operational shutdown scenarios to be applied in the event of threshold values being exceeded shall be clearly specified in the design.
- Systems will be designed to facilitate continuous data exchange with reliable meteorological data sources and central control systems.

1.18.3. Mass-Spring System

- The use of mass-spring systems will be assessed based on the need for vibration and noise reduction, limiting structure-track interaction, and improving passenger comfort.
- System parameters shall be determined taking into account train loads, operating speeds, ground conditions and the vibration sensitivity of surrounding structures.

- The design will be based on dynamic analyses and simulation results, taking into account long-term performance and maintenance requirements.
- Mass-spring systems will be designed to be compatible with other components of the track superstructure.

2. PLANNING, SITE SELECTION CRITERIA AND DIMENSIONING

2.1. ROUTE DETERMINATION

Terms related to the subject are listed below:

Approximate Location: An area of approximately 10 x 10 km² or of a similar or equivalent size, such as a settlement, neighbourhood, village, or any other area that can be identified by its name and coordinates, where a planned railway begins, ends or passes through

Corridor: An area approximately 10 km wide, with a length at least 1.5 to 2 times its width, encompassing the approximate starting and ending locations of a planned railway, and which can thus be described as a strip.

Approximate Alignment: Within a corridor, at a scale of 1:25,000, this refers to specific railway axis lines that are fully defined by the start and end coordinates of their linear and circular sections, as well as their curve radii; these may shift by up to 2 km to the right or left, in sections or along the entire length of the corridor, during subsequent planning and design stages. These axis lines, defined precisely in this manner, are sometimes referred to simply as the ‘alignment’ or ‘route’ unless there is a risk of them being interpreted differently in the context in which they appear.

Design Speed, Clearance, Axle Load, Load Classes: Information regarding route geometry and operational conditions is listed below. The values proposed in the designs are listed below. All values must be checked and applied in accordance with current regulations.

- Design speed is 160 km/h.
- Design shall utilise the LM71, SW/0 and SW/2 train loads defined in European specifications (UIC -71 and Eurocode 1991-2). Designs shall be prepared with a maximum axle load of 25 tonnes.
- The platform surface level shall be established at 550 mm above the rail level.
- The track gauge for a single-track line will be 1435 mm.
- The distance between the axes of the two tracks must be at least 4.0 m.
- The horizontal distance from the track centreline to the platform edge shall be determined by clearance calculations. Unless verified by clearance calculations, it shall be used as a minimum of 1750 mm.
- The freight traffic category shall be considered as Class E4 in accordance with the TSI.

Fatigue Load Design Requirements:

- Load model : in accordance with TS-EN1991-2 Annex D
- Verification Method : equivalent stress range based on the LM71 and λ"
- Design Life : 100 years

- Traffic Volume : 25 million tonnes per track per year, corresponding to 50 million tonnes per track per year for two tracks.
- Traffic Type : traffic with 250kN-axles

Design Train Characteristics:

Passenger Trains:

- Train length = 400m (Presence of trains in one or both tracks simultaneously shall be considered)
- Axle load = 170 kN

Freight Trains:

- Train length = 1000m (Presence of trains in one or both tracks simultaneously shall be considered)
- Axle load = 250 kN

2.1.1. Conducting the Corridor Study

Article 1) A planned railway with a defined function and approximate starting and ending points:

- Ability to fulfil the specified transport function,
- Geological and geotechnical suitability,
- Construction cost,
- Vehicle operating costs based on length of alignment & travel duration,
- Climate, elevation and maintenance and operational conditions expected to apply after construction,
- The national asset value of the land to be occupied,
- Impacts on the natural, socio-economic and historical environment,
- In terms of strategic importance and value,

Involves determining the most suitable, i.e. optimal, corridor and, within this corridor, the most suitable, i.e. optimal, approximate route based on the criteria listed above.

Article 2) According to this definition, there are multiple alternative corridors through which a planned railway, whose function and approximate starting and terminus locations have been determined, may pass. Theoretically, there will be a large number, and in practice, there will usually be more than one approximate route worthy of comparison. This comparison will be made in terms of the factors and considerations listed above. Whilst this comparison applies to a single corridor, in comparisons between corridors the corridor will represent the most suitable route determined in this manner; in other words, corridors will be compared with one another via their most suitable routes.

Article 3) Fundamentally, in order for two routes to be compared in terms of the points listed above, an objective and, undoubtedly, quantitative method, as explained in the following articles, is required. However, the fact that some routes are less suitable and less preferable than others may become evident from the outset through a purely qualitative assessment, without the need for detailed numerical analysis. This 'obvious' nature should apply not only to the project designer but to anyone examining the matter. Routes subject to such a qualitative assessment may not possess the characteristics of a 'alternative route' and may not be mentioned at all; or, even if they are mentioned, their numerical analysis may be omitted, with merely a qualitative demonstration of their unsuitability being sufficient, and their inclusion in the analysis in this manner may also be beneficial. Consequently, in principle, only routes worthy of being considered as alternatives will be examined and compared in detail.

Article 4) To ensure objectivity and to achieve this in the most appropriate manner, a suitable method for the comparisons—which are stated to require a numerical basis—is to consider each of the matters listed in Article 1 as factors and quantities that can be purchased, constructed, or provided, i.e. expressed in monetary terms, and to attempt to determine their monetary equivalents. The suitability and applicability of this method, along with the principles to be considered in the relevant application and how the proposed route can be expressed and characterised using a single cost item, will be examined in Article 5 below.

Article 5) As explained above, the most suitable route will be automatically determined in this way from among the alternative routes that have been analysed numerically and ultimately linked to a numerical characteristic representing either a monetary cost or a similar 'bad score', or conversely, a 'good score' expressed as a percentage. Indeed, the alternative route determined in this manner with the lowest cost, or the smallest negative score, or the highest positive score, will be selected as the most suitable, i.e. the optimal approximate route, for that corridor and representing it. The lowest cost, smallest negative score or highest positive score determined in this manner will also indicate the cost or score of the corridor in which the said optimal route is situated.

Article 6) By carrying out the process of determining the optimal approximate route, as explained up to this point, across all alternative corridors referred to in Article 2, the most suitable optimal corridor mentioned in the definition in Article 1 will also be determined; in other words, the corridor study project, the objective of which is to establish a unit specification, will have achieved its purpose. Indeed, in this case, just as described above, the corridor with the lowest cost or the lowest penalty score or the highest score will be selected as the most suitable optimal corridor.

Article 7) Regarding corridors for crossings, as explained in Article 3 above, the question arises as to whether they possess characteristics worthy of being considered as alternatives or alternatives; even if they appear worthy of examination in other respects, it may become

apparent from the very outset through qualitative assessments that certain corridors will not be used.

For example, it may be known from the outset that a corridor, even if its other characteristics are highly suitable, passes through a national park area or a region prohibited under a signed international environmental protection convention, and that proposing it would be inappropriate or, even if proposed, permission could not be obtained. Similarly, it may be known in advance that a corridor appearing suitable in many respects will not be used for strategic reasons.

As another example, a corridor passing through rugged and mountainous terrain with poor geological-geotechnical conditions at high altitudes, cannot serve as an alternative or alternative against another corridor that fulfils the transport function with the same efficiency—or even more effectively—and whose other characteristics are immediately and clearly superior at first glance; this can be demonstrated from the very outset without the need for a detailed examination.

In this way, whilst it may be beneficial for the sake of completeness to qualitatively demonstrate the characteristics of such corridors—which lack the potential to be serious alternatives—they should not be deemed ‘worthy of consideration’ and subjected to a detailed examination.

Article 8) As explained above, the first stage of corridor studies is to identify the possible corridors through which a planned route, whose function and approximate starting and terminating points have been determined, could be routed. In a significant part of the planning and design process, the starting and terminating points of the proposed railway line, together with its pre-determined function, will have already identified the corridor in question as the sole and non-alternative option.In the majority of actual situations, the transport function in question, together with the starting and terminus points, will also specify the intermediate mandatory locations that must be served along the route; consequently, the corridor that naturally emerges will generally have no alternative. Even if there are no such intermediate and mandatory points that serve to define the corridor, sometimes, for example, there will be a single physical passage, and thus one will again be dealing with a single, non-alternative corridor.

Just as with corridors, and for entirely similar reasons, the emergence of the most suitable route within a corridor—in a single, unavoidable manner—based on the railway’s intended transport function is a situation frequently encountered in planning and design. It is clear from the very definition of such studies that a corridor study will not be required for routes where both the corridor and the most suitable route within it can be derived directly from the intended transport function. Generally, the requirement for a corridor study for a planned railway is a matter to be determined and assessed by the Authority.

2.1.2. Identification of Alternative Corridors

As mentioned in Article 8, alternative corridor or corridors will be investigated only in cases where a single corridor option is not clear. The generally most suitable method for such corridor search studies is the use of existing or, preferably, updated 1:25,000 and larger-scale topographic maps. Among these, relief maps reflecting topography and physiography, which the General Directorate of Mapping has begun producing in recent years, are particularly useful and must be used if available. It is clear that similar studies previously commissioned by other public or private organisations for the same or different purposes may also provide significant benefits for EIA work; the Authority will provide the project team with those it deems useful and holds in its possession, and will assist in obtaining those it does not hold from the relevant organisations.

In general, it is almost always an unavoidable necessity to examine and evaluate the potential corridors identified on the basis of such maps and documents through on-site visits. In addition to all this, it is also of vital importance to understand and take into account the previous work and future plans and considerations of organisations such as the General Staff, the Ministry of National Defence, the General Directorate of Highways (KGM), the Turkish State Railways (TCDD), the General Directorate of State Hydraulic Works (DSİ), the General Directorate of Rural Services, the General Directorate of Electrical Works Studies, the Ministry of the Environment, and BOTAŞ, in relation to the corridors in question. To this end, whilst exploring opportunities for informal discussions and dialogue, the necessary correspondence must also be conducted with the assistance of the Administration and/or directly through the Administration. As mentioned in the preceding points and paragraphs, this information and data constitute matters that must already be considered and taken into account during the preliminary qualitative assessments of the corridor or corridors in question; in this way, corridors that are not feasible or valid will be identified from the outset, thereby preventing the unnecessary prolongation of the work and the resulting loss of time.

Regarding the planned railway, it is essential to identify all potential corridors capable of meeting a specific transport function—including those mentioned above that are ‘worthy of consideration’ but do not possess alternative status—and to carry out their initial qualitative assessments.

2.1.3. Examination and Evaluation of Alternative Routes

i. Within the corridors, potential routes—including those deemed “worthy of consideration”—will be subject to preliminary examination in the same manner as described above for the corridors; however, those without alternative status will be mentioned but will not proceed to the subsequent, more detailed examination phase. In order to identify the relevant characteristics of these routes, it may be necessary to create numerical models of the routes in question, as mentioned below, to determine, for example, their length, earthworks volumes and/or other specific characteristics.

Consequently, through these studies, all possible routes within the corridor under investigation must be sufficiently examined, all those that could be 'alternatives' must be identified, and those that do not meet these criteria must be explained with justification.

ii. Feasibility studies for the most suitable alternative routes within the identified alternative corridors will primarily be carried out using 1:25,000 scale maps. To this end, it is highly beneficial and necessary to digitise a sufficient section of these maps within the corridor to allow for the examination of the relevant alternative routes. It will generally not be possible or desirable to update these maps during the corridor study phase. However, to ensure that the alternative routes identified from the digitised models do not contain features that would compromise their suitability due to the maps being outdated, this must be verified through a sufficient number of site visits, along with photographs, sketches and notes taken during these visits and inspections, and through the geological and geotechnical studies to be carried out as detailed below.

iii. It is necessary for the alternative routes to be subjected to an objective numerical evaluation, and expressing this in monetary equivalents is likely the most suitable method. However, the project designer may also apply another scoring and evaluation method deemed appropriate by the Authority; in any case, the result of these evaluations must be expressed as a numerical value, based on whether the route in question is greater or lesser than that of the other route in the comparisons. In the explanations below, the comparisons listed in Article 1 are examined based on the monetary evaluation method as the primary factor; the explanations provided for this purpose should also be taken into account in other evaluation methods.

iv. The ability of the routes under consideration to fulfil the pre-defined transport function is largely a characteristic of the corridor in which they are situated; it can generally be said that different routes within the same corridor are in the same position and status in this respect, unless there is a clear reason to the contrary.

On the other hand, given the purpose of corridor studies and the methodology outlined in the preceding sections, the fulfilment of the transport function—or the degree to which it can be fulfilled—must be expressed numerically in an appropriate manner. This can be achieved, for example, by interpreting the fulfilment of the said function as a service targeted by the planned railway and identifying a suitable measure for the magnitude of this service. In equivalent terms, this volume can be considered as the total service volume to be provided by the railway under examination during the anticipated operational period.

Accordingly, the other matters listed in Article 1 and discussed below, namely

- Geological and geotechnical suitability and construction costs,
- Climate and altitude effects, as well as maintenance and operational activities,
- The impact of the natural, socio-economic and historical environment,
- The national asset value of the land to be occupied,
- Vehicle operating costs,

Refers to the inputs that must be incurred, borne or expended in order to produce the service volume in question, and which can, for example, be expressed in monetary terms in a quantitative analysis.

v. Geological and geotechnical suitability is not a factor for which a monetary equivalent is sought in its own right, but rather an indirect factor that influences the determination of the monetary equivalents of construction costs and, to a certain extent, maintenance, operation and environmental impact. In addition to this characteristic and its impact, geological-geotechnical suitability is a matter that must be carefully considered in corridor and route studies; therefore, it is mandatory for a comprehensive study to be carried out and reported at a scale of 1:25,000 for each corridor under examination.
The study in question will not generally involve costly field surveys such as drilling, geophysical surveys, test pits and the like, but will be based on comprehensive general geological modelling grounded in careful and sufficient expertise. This modelling should explain the tectonic system and other geological factors influencing the formation of the existing geological structure and morphology, and the stratigraphy of the corridor should be presented in sufficient detail. In addition to groundwater potential, structural geology should be presented alongside the necessary surface joint measurements; large-scale mass movements and various geotechnical problems that may be encountered during the construction phase, along with their preventative measures, should be attempted to be predicted. The estimated cost of these geotechnical measures, as will be discussed below, will be included in the construction costs and will largely determine the monetary equivalent of the geology-geotechnical comparison factor.

The geological and geotechnical studies to be submitted as part of the corridor surveys must include a report covering all the points outlined above, as well as a 1:25,000 scale map and cross-section of the corridor and the route under investigation. It is advisable to make use of similar and/or general geological studies and maps carried out by the General Directorate of Highways (KGM), the General Directorate of Mineral Research and Exploration (MTA), the General Directorate of State Hydraulic Works (DSİ) and similar organisations in the same corridor and/or region, and to make comparisons and corrections where necessary.

vi. Construction costs are one of the major expenditure items for the planned railway line and must be estimated with sufficient accuracy to enable proper comparisons. To this end, the
   - Earthworks and geotechnical measures,
   - Transport,
   - Bridges, underpasses and overpasses, hydraulic culverts,
   - Tunnels,
   - Superstructure and drainage systems,

- Landscaping, wire fencing, signage, safety and similar works,
- Volumes of other miscellaneous works

Efforts should be made to determine the total construction costs by calculating them in appropriate units and multiplying them by the relevant unit prices. It is clear that, at the corridor study stage, it is not possible to calculate these quantities and costs in the detail of preliminary or final project measurements and estimates; therefore, it is appropriate and sufficient to use more comprehensive unit rates derived from such detailed calculations on a one-off basis or updated from previous construction examples.

For example, provided that different pier heights and the use of pile or shallow foundations are considered separately, bridge costs can be determined on the basis of unit length costs. For culverts and other engineering structures, linear cost formulas that take the structure's length as a parameter can also be used for each cross-sectional dimension.

Similarly, determining tunnel construction costs based on tunnel length, taking into account various geotechnical conditions separately, may provide sufficient accuracy. Alternatively, these formulas could be refined to incorporate various ground rating systems—such as RMR and Q—as parameters, whilst also taking into account, on a case-by-case basis, the presence or absence of components such as ventilation and fire suppression systems depending on the tunnel length.

Superstructure costs can almost always be calculated with sufficient accuracy based on the route lengths established. Whilst it is not usually possible to say the same for landscaping, double-wire fencing, signage, safety measures and similar works, determining the costs of these activities by utilising the route length is a method that is frequently employed and, in some cases, the only option available. Another method that can be applied is to include the construction costs of these works as a percentage of the main construction items listed and explained so far—such as earthworks and geotechnical measures—in the same way as is frequently done for many other miscellaneous activities.

Using appropriately digitised 1:25,000 scale maps and a computer-generated model, it is possible to determine excavation and backfill volumes with a level of accuracy that is entirely sufficient for the purposes of this stage. By assigning appropriate classes to the excavation volumes determined in this way, based on the results of geotechnical studies, it is possible and sufficient to determine unit excavation costs with adequate accuracy using current unit prices and past or ongoing applications. Transport costs, on the other hand, can be determined approximately, taking into account the estimated quarry locations identified through geotechnical studies, or more accurately using Brückner calculations in a computer environment.

As explained above, working with numerical models in a computer environment is not only beneficial and accurate for volume and transport calculations, but is also essential for assessing the feasibility of the proposed route through cross-sections and for identifying the necessary geotechnical measures. Only in this way will it be possible to test numerous route options and select those that are feasible and recommendable.

The costs of geotechnical measures identified in these studies—such as retaining walls, gabions, shotcrete, ground anchors, bolting and similar elements—should be estimated separately using empirical formulas or based on past or ongoing construction practices.

Consequently, for the corridor studies in question, calculating construction costs by applying a fixed rate per unit length of railway—as is often done in feasibility and similar studies—constitutes a rough estimate; these costs should be determined with sufficient accuracy in accordance with the principles outlined above or by other methods. Accordingly, and as the above explanations also demonstrate, the horizontal and vertical geometry of the alternative route under consideration, together with;

- The railway's feasible cross-sections, excavation and backfill volumes, and estimated geotechnical measures,
- The lengths, estimated pier heights and foundation types of bridges, underpasses and overpasses,
- Tunnel lengths,
- The locations and approximate lengths of culverts and similar structures must be specified at a scale of 1:25,000.

vii. It is clear that the cost of the land to be acquired for the construction of the planned railway is an expense item that has been taken into account and will be incurred in order to provide the service capacity described in paragraph (iv) above. Determining the appropriate value for land that is to be allocated for the railway in such a way that it cannot be used for any other purpose may require different approaches and methods depending on the objective. It cannot be said that expropriation costs always reflect this cost item with sufficient accuracy. Indeed, under this method, it is possible for a valuable piece of land belonging to the Treasury or a forest area to be allocated for railway construction without compensation; this implies that the value of a resource that is currently productive and generating added value—or has such potential—is not accounted for as an expenditure item. Similarly, in current expropriation practices, situations frequently arise where the price is set below the value required by the actual and potential value created—or the potential to create such value—or, conversely, is set at a speculative level far above it; consequently, the relevant expenditure item may be overstated, with a larger or smaller portion than necessary being treated as a transfer expenditure within the national economy.
For the reasons outlined above and as a general approach, whilst the most accurate method for determining the cost of the occupied land as an expense item is to take into

account its actual economic value—that is, its value as part of the national wealth—based on the class and other characteristics and parameters of the land to be used in various categories, as determined from the agricultural land maps to be prepared, the views and recommendations of the Administration on this matter must also be followed. The land unit prices to be determined should be multiplied by the necessary areas to be calculated section by section, to which these unit prices will be applied, in order to calculate the total cost as accurately as possible.

viii. The largely negative impacts of the planned railway on the natural, socio-economic and historical environment are also costs that must be borne in order to achieve the targeted service volume; determining this cost objectively and accurately is arguably the most challenging aspect among the expenditure items under consideration. In these assessments, whilst there is a risk of falling into exaggerated subjective judgements on the one hand, on the other hand, there is a danger of disregarding or downplaying these negative impacts—as is frequently done by the very residents of the area through which the railway passes, who, in the case of a structure such as a motorway, expect large-scale services and benefits that are inconsistent with its function and have a low probability of materialising—especially given that environmental awareness has only recently begun to develop. Furthermore, in such assessments, it is essential to avoid the error of double-counting certain negative impacts, such as those related to agricultural land use.
In light of this difficulty, whilst numerical methods—such as assigning negative scores—may appear easier to implement than a monetary assessment of the adverse effects in question, this apparent ease generally stems from an implicit acceptance of the drawbacks and risks mentioned above and therefore requires careful consideration.

A level of precision sufficient for corridor studies can be achieved by taking into account certain negative impacts—where they exist—that are distinct and whose monetary costs can be calculated relatively easily, whilst also considering other impacts that are less distinct or more difficult to quantify, by expressing them as a percentage of the estimated total national income of the local population affected by the railway infrastructure under consideration, for example, over the operational period. as a percentage of their estimated total national income. Indeed, it is largely accurate to assume that both the scale and magnitude of the aforementioned adverse effects and the level of sacrifice the local population is prepared to make to mitigate these effects are proportional to the total national income in question; consequently, it can be assumed that the approach outlined above is based on a sound foundation.

In some cases, in order to arrive at a more accurate assessment, ready-made models and/or software designed to quantify the combined effect—using a wide range of environmental factors as parameters—may be utilised. However, in all circumstances,

every effort must be made to determine the appropriate method and to comply with the views and instructions of the Administration in such assessments.

However, with regard to the assessments in question and the considerations and requests concerning their accuracy and methodology, it should be borne in mind that the identification of environmental and socio-economic impacts cannot be expected to be carried out within the scope and level of detail of an EIA and/or feasibility study, and that, as a cost item, the calculations to be carried out in accordance with the above considerations and explanations will generally be sufficient for the purpose of the studies in question. Another point worth considering is that, for crossings within the same corridor, the magnitude and order of magnitude of these adverse effects will generally be similar to one another; whilst their significance and impact will be felt more in comparisons between corridors, they will nevertheless remain of a secondary nature compared to other comparative factors in this regard.

ix. Once the railway has been completed and put into operation, whilst the capacity for the targeted service provision has been established, in order to ensure that this is maintained and sustained throughout the operational period , the structure—including the tunnel, bridges, engineering structures, superstructure, drainage system and all other components—must be maintained, illuminated and ventilated; in short, a series of operational activities, each constituting a separate cost item, must be carried out, and these will undoubtedly increase the unit cost of the service provided. On the other hand, it is to be expected that these costs will vary not only between potential routes within the same corridor but also from one corridor to another; this is a common scenario and, as such, it is clear that these variations will serve as a factor influencing the comparison between them and the selection of the most suitable transport corridor. The determination and calculation of maintenance and operating costs is also a complex and challenging task; it is both expected and desirable that railway operators should have models in place—which they have developed, utilise and continuously update—for estimating these costs. Even if this is not the case, it is beneficial, necessary and mandatory to make use of the studies carried out or commissioned by the Authority and the data provided, and to act in accordance with its views and instructions.

Even in the absence of these, such costs can be deemed acceptable and/or quantifiable on the basis of certain fundamental principles, thereby enabling a proper comparison of the options in terms of maintenance and operational factors.

Maintenance and repair of superstructures, head and fill ditches, railwayside ditches, drop channels, culverts and maintenance and repair of the drainage system including other elements; tunnel lighting, ventilation and other components, and overall tunnel maintenance and repair, Maintenance and repair costs for engineering structures such

as underpasses, overpasses and bridges, and in addition to these, maintenance costs arising from geotechnical design and protection elements and soil surfaces must be aggregated to determine a separate maintenance and operating cost per unit kilometre for each alternative.

x. Vehicle operating costs are directly dependent on the physical conditions of the railway, its length and geometric standards. Compliance with geometric standards is the most decisive factor. In other words, an alternative route featuring small horizontal curves, steep gradients and a relatively longer alignment will incur higher vehicle operating costs than another. Accordingly, any geometric differences and variations in route length among the options will significantly alter unit service costs; however, in principle, the volume of service provided will remain the same regardless of the travel distance between the same departure and arrival points. Consequently, options offering shorter travel distances will be significantly more advantageous in terms of unit service costs. In fact, due to the time factor not being taken into account in a study of the precision of a corridor study, the volume of service provided for the same departure and arrival points decreases slightly with the journey length; or, if the service volume is kept constant, the cost increases accordingly, meaning that the advantage offered by a shorter journey length is further enhanced.
According to these explanations, it is of vital importance that vehicle operating costs are determined with sufficient accuracy.

xi. The strategic importance cited in Article 1 as a numerical comparison element is not so much a cost item to be expressed as a numerical scoring factor or monetary equivalent, but rather, as explained in the preceding article and paragraphs, a matter to be taken into account in qualitative assessments; it must be examined and utilised in accordance with the principles and objectives outlined there.

The sum of the costs discussed in paragraphs (v) to (xi) above, and for which methods of determination have been outlined, will constitute the cost that must be taken into account to provide the total services targeted for the route under consideration. However, as the volume of services that can be provided in this manner may vary from one route to another, these costs alone may not be meaningful or suitable for comparison. On the other hand, the unit service cost—calculated by dividing the total costs, as per paragraph iv, by the total service volume (adjusted where necessary for the reasons explained in that paragraph) is clearly a more appropriate indicator of the economic viability and efficiency of the solution provided by the route under consideration and can be used as the final numerical parameter representing that route in comparisons. It is clear that the fact that this parameter, in the form described, takes on a small value constitutes a disadvantage.

Up to this point, whilst this method has been examined as an example to illustrate the fundamental principles and, where appropriate, the details that must be taken into account in

assessments, other numerical analysis and scoring methods deemed suitable by the Authority may also be applied; in such cases, the same principles must be adhered to and the necessary details must be taken into account.

Once these parameters have been expressed in definitive numerical values, the determination of the most suitable route and the most suitable corridor will be carried out in accordance with Articles 2 and 3.

2.1.4. Documents to be Submitted for Route Determination

As a result of the work to be carried out in accordance with the matters and principles detailed in the preceding articles and paragraphs, the following documents will be prepared and submitted to the administration.

i. Plan and profile sheets at a scale of 1:25,000, showing the alignment axes and profiles, will be drawn separately for each alternative corridor and route. On these sheets, the corridor and option names will be indicated, and other alternative alignments entering the sheet apart from the one being submitted will also be shown in a different drawing mode. The plan sheet in question will specify the kilometreage of the alignment under consideration, along with the minimum number of coordinates and curve radius values necessary to define the alignment. The use of clothoids is not required for alignments created during the corridor study phase. On the profiles, gradients, kilometre points and vertical curve radii shall be indicated, and tunnels, bridges and engineering structures shall be shown at their estimated locations using appropriate symbols. It would also be appropriate to indicate their estimated abutment heights, lengths and other relevant dimensions. The cross-sections in the plan section of the aforementioned sheets must be shown together with a 1:25,000 scale digitised map background.
ii. The 1:25,000-scale geological plans and sections, to be created in the same number as the plan-profile sheets mentioned in the preceding paragraph as a result of the studies conducted in accordance with the principles governing the examination and evaluation of alternative routes, shall be prepared and submitted in accordance with geological engineering rules, specifications and relevant AYGM standards. In the plans and profiles, units and formations, strata, faults, fractures, breaks, landslide and slip lines and areas shall be shown using appropriate symbols and logos, and the sheets shall be coloured where necessary.
iii. Where the tunnel alignment intersects or approaches identified fault zones, the Contractor shall carry out a dedicated fault zone crossing risk assessment. This shall include characterisation of fault geometry, extent, and hydrogeological properties, assessment of ground behaviour during crossing, and specification of support and monitoring measures tailored to fault zone conditions.
iv. Agricultural land use maps at a scale of 1:25,000 will be created based on the maps and data prepared by the Ministry of Agriculture and Forestry. In these maps, the soil classes determined and used by the aforementioned ministry will be included exactly

as specified and presented using the same colours and symbols. As the maps prepared by the Ministry are outdated and have not been updated, any necessary corrections based on field surveys and observations will be indicated, along with their justifications. The information generated within the scope of these studies will be used as fundamental data in determining the national asset value of the land to be occupied and in assessing the impacts on the natural and socio-economic environment.

v. All findings and data generated as a result of the geological and geotechnical studies conducted within the framework of the principles governing the examination and evaluation of alternative routes will be presented in full in a “Corridor Geological and Geotechnical Report”. The report will summarise the studies carried out, the methods applied, and the previous studies utilised as sources, and within the framework of the geological model or models established for the corridor or corridors based on the results obtained,

- General geology and dominant tectonics,
- Stratigraphy,
- Structural geology, faults, fractures, bedding and discontinuities,
- Active, passive and/or potential landslide and slope failure areas,
- Groundwater,

will be explained within a logical framework, and an attempt will be made to anticipate the geotechnical difficulties that may be encountered during construction and the measures to be implemented.

The report will be presented in a clear and informative manner, introducing the site, and will be supplemented with maps, diagrams and photographs.

vi. The corridor study works to be carried out in accordance with all the principles and details presented thus far will be described and concluded in a “Corridor Study Report”. The report will primarily cover the matters detailed and examined in the preceding sections and paragraphs, whilst

- The subject and purpose of the study,
- The method applied in accordance with the requirements and principles set out in this unit price schedule, the sources utilised and previous studies,
- Information regarding the transport function of the railway under review and the transport studies carried out and their results,
- A spatial overview of the corridors under review,
- For each corridor:
    - Ability to fulfil its transport function,
    - Strategic importance,
    - Physical geography and climate,
    - Natural, socio-economic and historical environment and their interactions,
    - Geological and geotechnical suitability,
    - And other considerations

a general and qualitative analysis

- For each of the alternative corridors identified as a result of the qualitative review and assessment:
    - Route determination studies and, as with the corridors, a qualitative analysis and evaluation regarding the identified routes,
    - Regarding the alternative routes identified as a result of the preliminary assessment, a numerical analysis and/or the determination of cost items, total costs and unit service costs, as detailed in clauses 2.1.2 and 2.1.5,
- Comparisons and the identification of the most suitable option,
- The need to meet and/or revise the transport function, if necessary,
- Conclusions and recommendations

shall be presented in a logically coherent manner, as comprehensively as possible and with the necessary detail.

2.2. CRITERIA FOR ROUTE SELECTION AND SIZING OF BRIDGES, VIADUCTS, TUNNELS AND RETAINING STRUCTURES

The necessity for engineering structures such as bridges, viaducts, tunnels and retaining structures is determined during route selection. Similarly, the length of the planned engineering structure will be determined by the geometric constraints of the route. In structures with a platform width, such as bridges, viaducts or tunnels, the platform width will be determined according to the dynamic gauge, which is established based on the number of lanes, the type of vehicles to be carried, and the design speed.

For bridges, viaducts, tunnels and retaining structures, all alternative types

- initial construction cost
- annual maintenance and repair costs
- construction period

will be assessed taking these into account and submitted for the authority’s approval.

3. GEOMETRIC DESIGN

This section will set out the limit values for the geometric design criteria of lines. The specified criteria will apply to all design stages of horizontal and vertical route geometry, including main lines, branch lines (parking tracks on the line, depot connection tracks, etc.), and all track designs on depot lines.

3.1. INTRODUCTION

The primary objective of the geometric design criteria is to ensure that lines provide an efficient, cost-effective, sustainable and comfortable transport service whilst meeting sufficient safety factors in areas such as operation, maintenance and vehicle safety. When designing the geometry of railway systems, a holistic approach must be adopted, taking into account factors such as construction, operation, vehicle and track maintenance, and passenger comfort.

In the development of the geometric design criteria, use has been made of the national and international standards and regulations listed in Table 3.1. The railway system design to be carried out will be compliant with these standards.

Table 3.1 : Sources referenced for geometric design criteria

STANDARD NO	STANDARD/REGULATION NAME
TS EN 13803	Railway applications – Track – Track alignment design parameters – Track gauges 1 435 mm and wider
TS EN 13674-1	Railway applications – Railway track – Rail – Part 1: Vignole railway rails of 46 kg/m and above
TS EN 13452-1	Railway applications – Braking – Mass-transmission braking systems – Part 1: Performance rules
UIC 703	Route characteristics for high-speed passenger rail lines
AREMA	American Railway Engineering and Maintenance-of-Way Association – Railway Engineering Manual – Section 6 Railway Line Design
TCRP Report 155	US Federal Transit Administration – Transit Research Programme Report 155 Design Manual for Light Rail Systems

Table 3.2 : Definitions for geometric design criteria

DEFINITIONS	
Main line	A railway line extending between two stations and passing directly through the stations.
Branch line	Railway lines constructed to assist main lines, such as depot and maintenance yard lines, stabling lines and depot connection lines.
Limit value	Refers to the maximum or minimum limit values that must be adhered to in the design.
Absolute limit value	Refers to the minimum or maximum limit values that are recommended to be adhered to in exceptional circumstances.
Unbalanced lateral acceleration	The lateral acceleration experienced by a passenger whilst the rail vehicle is traversing a horizontal curve.
Jerk	A comfort parameter describing the variation over time of the lateral acceleration experienced by passengers as a rail vehicle in motion passes through a horizontal curve.
Alignment	A section of the rail system track where the track runs straight.
Curve	A section of track connecting two straight sections via a circular curve.
Transition Curve	A curved section of track that connects straight and curve sections, making the transition smoother.
Vertical gradient	The change in elevation within a given horizontal distance on a railway line. It is usually expressed as a percentage.
Superelevation	This is the vertical height given to the outer rail of the curve centre relative to the inner rail, in order to counteract the centrifugal force generated during a horizontal curve transition and to ensure a comfortable ride.

DEFINITIONS	
Counter-steering (theoretical)	The theoretical amount of superelevation required to balance the centrifugal force generated in the vehicle at a given speed V and reduce lateral acceleration to zero.
Practical superelevation	This involves reducing passenger comfort under certain conditions to bring the theoretical superelevation down to a practical value.
Uncompensated superelevation	The difference between the balancing load and the applied load. It is also referred to as a load deficiency.
Static gauge	Refers to the area occupied by a vehicle when stationary on a straight section of track without passengers.
Dynamic gauge	Refers to the area occupied by a moving vehicle on a straight or horizontal/vertical curved track section, taking into account factors such as suspension conditions, rail and wheel wear, and horizontal and vertical sway.
Vehicle gauge	Defined as the space occupied by the vehicle, with a 100 mm safety margin added around the dynamic gauge.
Simple switch	A switch structure that facilitates the transition from one track to another via a diverging route.
S-type switch area	A switch system that provides a connection in a single direction between two parallel tracks, with a simple switch on each track.
Crossing switch section	A switch system that provides a connection in two directions between two parallel tracks, consisting of two simple switches on each track and a crossover at the point of intersection.

3.1.1. Design Speed

The main line geometry will be designed for a design speed of 160 km/h. The design must be prepared for a speed of 160 km/h and tested at 176 km/h to ensure compliance with comfort criteria. The speeds to be used in the geometric design are summarised in Table 3.3 at. Where required by the project, lower design speeds may also be used by imposing a speed restriction.

Table 3.3 : Design speeds

TRACK SECTION	DESIGN SPEED (km/h)	CONTROL SPEED (km/h)
Main Line	160	176
Connection Line	70	77

3.1.2. Passenger Comfort

The acceleration values to be considered in railway main lines shall comply with the EN 13803 standard.

To ensure a comfortable journey for passengers, the values of unbalanced lateral acceleration acting on passengers on horizontal curves shall not exceed the limit values given in Table 3.4 at.

Table 3.4 : Limit values for unbalanced lateral acceleration

	MAXIMUM LIMIT VALUE	ABSOLUTE MAXIMUM LIMIT VALUE
Unbalanced Lateral Acceleration (Main line)	1.00 m/s^2	1.50 m/s^2

3.2. HORIZONTAL AND VERTICAL ROUTE

3.2.1. General

These criteria shall be applied to the geometric design of the main line, branch lines and depot/maintenance yard lines at all stages of the horizontal alignment design.

The horizontal alignment of main lines shall consist of transition curves, straight (alignment) sections and circular arcs (curves). The horizontal alignment on the main line consists of straight sections connected to circular curves by transition curves. Where appropriate, the maximum speed on the curved sections of the line will be maintained by means of a cant, limited to a maximum of 130 mm.

Design Speed: 160 km/h (Passenger)

Minimum Horizontal Curve Radius to be compatible with the design speed

Minimum Vertical Curve Radius to be compatible with the design speed

Maximum Cant (h) 130 mm

Maximum Cant Deficiency 150 mm (exceptional)

Maximum Cant Excess 110 mm (EN 13803)

Minimum Clothoid Length to be compatible with EN 13803

3.2.2. Alignment

3.2.2.1. Tracks

The minimum alignment length (L_a) between two curves on the main line shall be determined based on the principle of the distance covered by a vehicle in 2 seconds. In exceptional cases, the $L_a$value may take the absolute minimum value calculated as the distance between bogie centres plus 1 (one) bogie length.

The minimum distance between two horizontal curves must be taken as V/2 m.

3.2.2.2. Stations

The horizontal geometry at station crossings shall be designed as a straight line. The straight-line section shall be extended 20 m (based on the distance between bogie centres plus one bogie length) from each end of the platform. The length of spiral transitions extending beyond the end of a platform shall be a minimum of 25 m, of which 17 m shall be without a curve. In exceptional cases, a station may be designed with a curve in accordance with the conditions specified in Section2.2.3.1.

3.2.2.3. Special Track Works

All special track works shall be carried out on straight track. Points shall under no circumstances be designed on a horizontal curve. On the main line, a straight track section meeting the minimum alignment length criteria shall be left between two sets of points, between the end of a horizontal curve and a set of points, and between a station or any special track structure and a set of points. On tracks within the depot and maintenance area, this distance shall be a minimum of 15 m.

Table3.5 : Minimum alignment lengths

TRACK SECTION	MINIMUM LENGTH (m)	ABSOLUTE MINIMUM LENGTH (m)
Main Line	L_a = 0.56*V	V/2
Depot and Maintenance Area Lines	L_a = 0.56*V	15
Station Entrances and Exits	20	-
Special Line Works (On the main line)	L_a = 0.56*V	V/2
Special Line Works (Depot-maintenance area)	L_a = 0.56*V	15

3.2.3. Curves

3.2.3.1. Circular Curves

Circular curves shall be defined by their radii in metres. To ensure a comfortable and safe journey, curves shall have as large a radius as possible. The following speed calculation shall be satisfied on main lines where minimum curve radius can not be applied due to geometrical restrictions.

$$V_{\max} = \sqrt{\frac{(h + h_d)\,R}{11.8}}$$

Where;

$h = \text{allowed cant}$

$h_d = \text{allowed cant defficiency}$

$R = \text{curve radius}$

$V_{max} = \text{speed } (\frac{\text{km}}{\text{h}})$

The minimum curve radius of the main line will be determined based on the design speed and gradient limits.

No points shall be designed on horizontal curves.

As specified in the relevant clause, on lines where the design speed differs from 160 km/h, the minimum horizontal curve radius shall be calculated according to the following formula.

$$R_{min} = \frac{11{,}83 \times V^2}{D_u + 153 \times a_d}$$

R_{min} : Curve radius (m)

V: Design speed (km/h)

D_u : Application deviation (mm)

a_d : Uncompensated lateral acceleration ($^{m/s^2}$)

The required minimum length of a circular curve (L_k) shall be determined according to the formula L_k= 0.56*V. Here, the value of V is the design speed expressed in km/h. In exceptional cases, the absolute minimum length of the curve shall be taken as V/2 m.

In double-track curves, when selecting the clearance requirements and the minimum clearance between the track centre lines, the smaller of the two radii shall be taken as the basis.

The values specified in the below table shall be regarded as minimum values, subject to the approval of the Employer. During implementation, every effort shall be made to achieve higher values wherever practicable.

Table3.6 : Limit values for circular curves

	MINIMUM LIMIT VALUE	ABSOLUTE MINIMUM LIMIT VALUE
Curve Radius (On the main line – for V: 160 km/h and 120 km/h)	1500 m	1000 m
Connection Line Curve Radius (for V = 70 km/h)	200 m	200 m
Curve Length	L_k = 0.56*V	V/2
Curve Length (Depot-maintenance area)	L_k = 0.56*V	15 m

3.2.3.2. Curves

Although the use of compound curves is not recommended, they may be used where necessary to overcome physical or operational constraints. Where two or more circular curves

are to be connected to form a compound curve, the circular curves shall be joined by transition curves, and the gradient of each curve shall be adjusted so that the permissible maximum speed remains the same throughout the entire compound curve.

3.2.3.3. Reverse Curves

The use of reverse curves shall not be preferred as they adversely affect driving comfort and the structural characteristics of vehicles. In cases where it is impossible to create a straight section between reverse curves due to extremely restrictive geometric conditions, the reverse curves shall be connected by spirals.

3.2.4. Cant

Cant is the vertical height given to the outer rail of a curve relative to the inner rail, intended to counteract centrifugal forces and ensure passenger comfort. Where necessary, superelevation shall be provided to the rails on all curves in accordance with the following formulae.

If horizontal curves are located in areas where acceleration increases or decreases, adjustments to the cant within the curve will be considered to minimise the instability caused by varying speeds.

3.2.4.1. Balancing (Theoretical) Gradient

The balancing gradient (D_t), is the theoretical radius that must be provided to the outer track relative to the inner track along a curve, which balances the centrifugal and centripetal forces acting on a vehicle travelling at a given speed V whilst negotiating a horizontal curve, thereby reducing the lateral acceleration to zero. The value of D_t is calculated according to the following equation:

$$D_t = \frac{11{,}83 \times V^2}{R}$$

D_t: Balancing cant (mm)

V: Design speed (km/h)

R: Curve radius (m)

3.2.4.2. Application Deflection

The balancing gradient (D_t) is the theoretical cant at which the lateral acceleration acting on the passenger is zero. For practical purposes, the D_t value may be reduced to the applied cant (D_u) value, taking into account the maximum lateral acceleration values given in Table 2.4. The $D_u$value will be calculated using the following equation:

$$D_u = \frac{11{,}83 \times V^2}{R} - 153 \times a_d$$

D_u: Applied deflection (mm)

V: Design speed (km/h)

R: Curve radius (m)

a_d: Unbalanced lateral acceleration (m/s^2)

If the calculated D_u value falls below 20 mm, it will not be taken into account. The maximum permissible deflection will be 130 mm.

3.2.4.3. Unbalanced Load

Unbalanced deflection (I) will occur when the theoretical deflection is reduced to the applied deflection within an acceptable lateral acceleration range. Unbalanced deflection will be calculated using the following formula.

$$I = D_t - D_u$$

I: Unbalanced deflection (mm)

D_t : Balanced deflection (mm)

D_u : Applied deflection (mm)

The amount of unbalanced deflection must not exceed 110 mm. In exceptional cases, the limit value may be taken as 130 mm.

Unbalanced lateral acceleration values must be calculated using the following formula in terms of unbalanced deflection, and it must be confirmed that they do not exceed the values in Table2.4.

$$a_d = \frac{g}{e} \times I$$

a_d : Uncompensated lateral acceleration (m/s^2)

g: Gravitational acceleration (9.81 m/s^2)

e: Track centre-to-centre distance (1500 mm for standard track gauge)

I: Unbalanced overhang (mm)

3.2.4.4. Cant Application

The selection of the required superelevation for a given curve shall be subject to the following criteria:

Maintenance of maximum speed along the curve,

Ensuring passenger comfort at the desired level,

Selection of the minimum superelevation value.

The cant application will be applied linearly along the transition curve. The application cant will be determined in multiples of 5 millimetres.

3.2.5. Transition Curve

Transition curves shall be applied where the route transitions from straight sections to curved sections, or in the case of compound curves, in order to ensure passenger comfort, the integrity of the superstructure and the protection of the vehicle. Curves such as the spiral (clothoid), cubic parabola, sinusoid and similar curves may be used as transition curves. The most commonly used transition curve is the spiral (clothoid) curve.

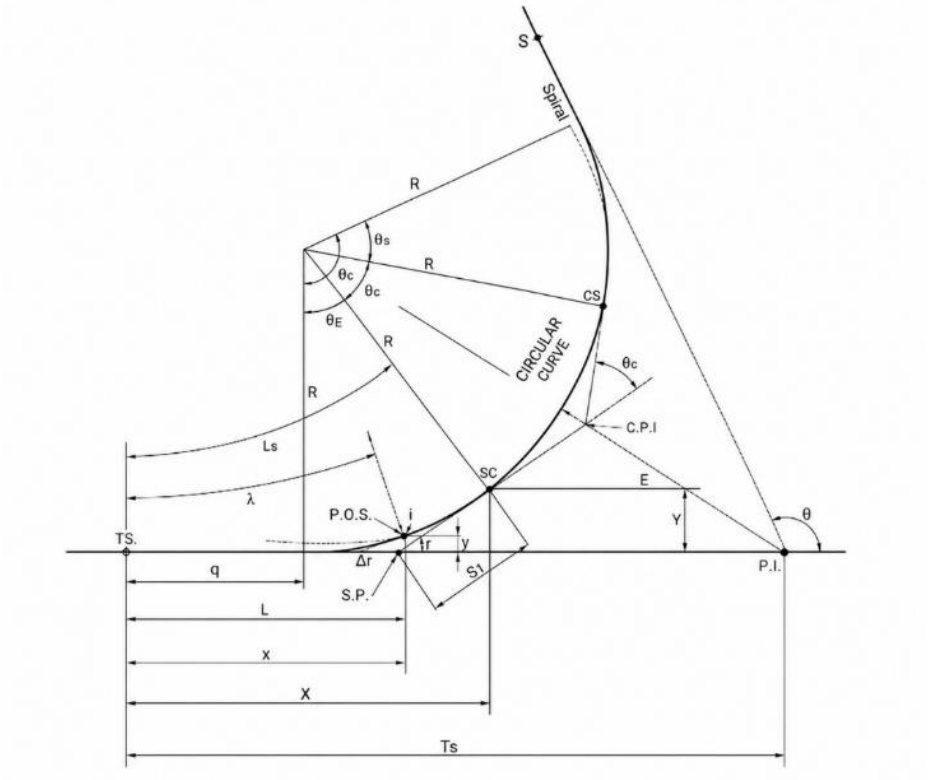


Figure3.1 : Transition curve – spiral (clothoid)

B: the deflection angle at point B (degrees)

C.P.I.: the point where the straight lines intersect the circular curve

C.S.: the point where a circular curve transitions to a spiral curve

E_t: distance between the circular curve originating from the centre of the circle and P.I L_s: actual spiral length (m)

p: the ordinate distance (m) between the point where the radius of the circular curve is perpendicular to the spiral's long axis (l.t) and T.S.

P.I.: the point of intersection of the two generating lines P.O.S.: a point on the spiral

q: the abscissa distance (m) between the point where the radius of the circular curve is perpendicular to the spiral's long line (l.t.) and T.S.

R: radius of the circular curve or the end of the spiral (m) S.C.: point where the spiral curve transitions to the circular curve

S.P.I.: the point of intersection of the long and short lines

S.T.: the point where the spiral curve transitions to a straight line s.t.: short straight line

T_s: the length of the main straight line between T.S. or S.T. and P.I. (m) T.S.: the point where the straight line transitions to the spiral curve

X: the abscissa distance between T.S. and S.C. or S.T. and C.S. (m) x: the abscissa distance between T.S. and P.O.S. (m)

Y: the ordinate distance between T.S. or S.C. and S.C. (m) y: the ordinate distance between T.S. and P.O.S. (m)

Δ_r: The angle, expressed in radians, between the straight line and the long straight line at P.O.S.

The limit value isθ_s.

θ: total central angle (degrees)

θ_c : the central angle of the circular curve (degrees)

θ_s : total spiral angle (degrees)

λ: The partial length-limit value L_s(m) is between the spiral curve's T.S. or S.T. and any point (P.O.S.) on the spiral.

The minimum spiral length (L_s) will be determined based on the maximum value resulting from the calculation of the following parameters.

The time derivative of the deviation (dD_u/dt),

The time derivative of the unbalanced deviation (dI/dt)

The slope of the deviation (dD_u/ds)

The change in the wave with respect to time will be calculated using the following formula. It is recommended that this value does not exceed 50 mm/s. The absolute maximum value is 70 mm/s.

$$\frac{dDu}{dt} = \frac{Du \times V}{3{,}6 \times Ls}$$

dD_u/dt: Rate of change of displacement over time (mm/s)

D_u: Applied deflection (mm)

V: Design speed (km/h)

L_s: Transition curve length (m)

The change in unbalanced deflection over time will be calculated using the following formula. It is recommended that this value does not exceed 55 mm/s. The absolute maximum value is 100 mm/s.

$$\frac{dI}{dt} = \frac{I \times V}{3{,}6 \times Ls}$$

dI/dt: Rate of change of the unbalanced deflection over time (mm/s)

I: Unbalanced deflection (mm)

V: Design speed (km/h)

L_s: Transition curve length (m)

The gradient of the slope will be calculated using the following formula. It is recommended that this value does not exceed 2.00 mm/m (1/500). The absolute maximum value is 2.50 mm/m (1/400).

$$\frac{dDu}{ds} = \frac{Du}{Ls}$$

dDu/ds: Slope (mm/m)

D_u: Application slope (mm)

L_s: Transition curve length (m)

The control values for parameters related to the transition curve and slope are summarised in Table 3.7.

Table3.7 : Control values related to the transition curve and gradient

PARAMETER	MAXIMUM LIMIT VALUE	ABSOLUTE MAXIMUM LIMIT VALUE
Rate of Change of Cant	50 mm/s	70 mm/s
Rate of Change of Cant Defficiency	55 mm/s	100 mm/s
Cant Gradient	2.00 mm/m (1/500)	2.50 mm/m (1/400)

When determining the transition curve length, the equations in Table 3.8 will be used in accordance with these limit values. The maximum value resulting from the calculations will be selected as the transition curve length. For practical purposes, the resulting value will be rounded up to the nearest multiple of 5.

Table 3.8 : Equations for transition curve length

EQUATION NO	EQUATION
1	$L_S = \frac{5{,}6 \times V \times D_u}{1000}$
2	$L_S = \frac{5{,}1 \times V \times I}{1000}$
3	$L_S = 0{,}5 \times D_u$

L_s: Transition curve length (m)

D_u: Application deflection (mm)

I: Unbalanced deflection (mm)

V: Design speed (km/h)

3.2.6. Ramp

The cant transition shall normally coincide with the horizontal transition curve. Its length and profile, including any smoothing at its ends, shall be designed in accordance with EN 13803:2017 for a design speed of 160 km/h. Compliance with the applicable limits for cant gradient, rate of change of cant, and rate of change of cant deficiency shall be demonstrated by calculation.

3.3. VERTICAL ALIGNMENT

3.3.1. General

These criteria shall be applied in the geometric design of the main line, branch lines and depot-maintenance yard lines throughout all design stages of the line's vertical alignment.

The vertical alignment will consist of vertical straight sections where the longitudinal gradient is linear, and vertical curves. The track profile is a longitudinal section showing the top level of the track at the lowest elevation at the centre of the track.

3.3.2. Gradients

3.3.2.1. Main Lines

The maximum continuous gradient shall be 16.0%o. The minimum length of the continuous gradient shall be calculated as L_v= 0.56*V (m), where V is the design speed (km/h). In exceptional cases, the length of the continuous gradient may be set to a minimum of 20 m. In the design of main and branch lines, to ensure adequate drainage, the most effective method in practice will be to provide discharge channels at low points by incorporating longitudinal gradients of 0.5% along the line. The application of a 0% gradient over long distances will be avoided. Where consecutive gradients are used, the aesthetic appearance of the line (particularly the viaduct alignment) shall not be adversely affected.

Where required by geometric and topographical conditions, gradients exceeding 16.0% (up to 20.0%o may be used. Gradients forming dip (valley) stations shall be avoided.

3.3.2.2. Station Line

A gradient of 0.0%o shall be preferred in station areas. No change in gradient shall be permitted within 20 m of either end of the platform (based on the distance between bogie centres plus one bogie length). In unavoidable cases, the maximum gradient shall not exceed 5%o for above-ground stations and 3%o for underground stations.

3.3.2.3. Special Track Works

All special track works shall be carried out on a level track. On the main line, a straight track section shall be left between two points, between the vertical curve end and a point, and between a station or any special track structure and a point, in accordance with the minimum vertical alignment length criteria. In exceptional cases, switch areas may be designed on a graded track provided that the limit values are not exceeded. These limit values are 5.0%o for simple switches on the main line, 5.0%o for S-switch areas, and 5.0%o for cross-over switch areas. Turnouts in the depot and maintenance area shall be installed on level track on concrete-fixed and ballasted tracks. However, in exceptional cases, vertical gradients of 5.0%o in the simple turnout region and 5.0%o in the cross-over region may be applied for ballasted tracks.

The limit values for vertical gradients in geometric design are summarised in Table 3.9.

The values specified in the below table shall be regarded as minimum values, subject to the approval of the Employer. During implementation, every effort shall be made to achieve minimum gradient values wherever practicable.

Table3.9 : Vertical gradient limit values

TRACK SECTION	MAXIMUM LIMIT VALUE	ABSOLUTE MAXIMUM LIMIT VALUE
Main Line	16.0‰	20.0‰
Depot-Maintenance Area Lines	0.0‰	3.0‰
Internal Depot Area Connection Lines	1.5	-
Station Line	0.0‰	3.0‰
Special Line Works – Simple Switch	0.0‰	5.0‰
Special Line Works – S-type Switch	0.0‰	5.0‰
Special Line Works – Cross Switch	0.0‰	5.0‰

3.3.3. Vertical Curves

Where there are changes in track gradient, vertical curves shall be used to provide a smooth transition. Open or closed vertical curves shall be selected as large as possible. Vertical curves shall be formed using circular or parabolic curves.

3.3.3.1. Vertical Curve Radius

The minimum vertical curve radius on the main line shall be calculated using the following formula.

$$R_v = \frac{V^2}{2}$$

R_v : Vertical curve radius (m)

V: Design speed (km/h)

The calculated minimum vertical curve radius shall not be less than 13000 m (for: V:160 km/h).

3.3.3.2. Vertical Curve Length

The vertical curve length (L_v, m) on the main alignments shall be calculated using the following formula. The calculated vertical curve length shall not be less than 60 m.

$$L_v = 30 \times (G_1 - G_2)$$

(G_1– G_2): The algebraic difference of adjacent gradients (absolute value)

Where horizontal and vertical curves meet, the minimum vertical curve length shall be calculated using the following formula.

$$L_v = 60 \times (G_1 - G_2)$$

4. CONSTRUCTION AND STRUCTURAL DESIGN

4.1. GENERAL

This section covers the criteria and design rules to be considered during the project processes for the construction and structural design of railway projects.

This section covers national and international standards, regulations, technical documents and other design specifications relating to track structures, temporary and permanent structures, excavation support systems, structural design procedures for tunnels, as well as geotechnical instrumentation, drainage and fire design in railway systems to be constructed.

This section draws upon laws, decrees, regulations, circulars, specifications and standards published by the official institutions and organisations of the Republic of Turkey, as well as standards published by TSE; where standards and specifications are insufficient, reference has been made to standards and technical documents such as TS EN, AASHTO, AREMA, AISC, IBC, ACI, NFPA, FHWA, PTI, ITA, BS, UIC, ISO, DIN, TSI, and other technical documents.

4.2. STANDARDS

4.2.1. Standards

- TS ISO 9194 Principles of structural design – Load-bearing and non-load-bearing elements – Density of stored materials
- TS 708 Reinforcing Steel for Steel-Concrete Composites
- TS EN 206 Concrete – Properties, performance, production and conformity
- TS EN 1536: Special geotechnical applications – Driven (fore) piles
- TS EN 1537: Special geotechnical applications – Ground anchors
- TS EN 1991-1-3 2009 Actions on structures – Part 1-3: General actions, snow loads
- TS EN 1991-1-4 2005 Actions on structures – Part 1-4: General actions, wind actions
- TS EN 14490: Specific geotechnical applications – Ground nails
- TS 3434 Civil Engineering and Building Technical Drawings – Specification of Section and Elevation Areas – General Rules
- TS 3532 Technical Drawing – Scales
- TS 3710 Technical Drawings for Building and Civil Engineering – Reinforcement Symbols for Reinforced Concrete
- TS 3816 Technical Drawings for Building and Civil Engineering – Rules for the Arrangement of Reinforcement Schedules

- TS 213 Concrete Floor Slab Panels TS 498 Design Values of Loads to be Considered in the Dimensioning of Structural Elements
- TS 500 Design and Construction Rules for Reinforced Concrete Structures
- TS 647 Calculation and Construction Rules for Timber Structures
- TS 1500 Soils in Civil Engineering – Classification
- TS 2119 Building Architectural and Construction Drawings – Drawing of Plans, Scales
- TS 2317 Building and Architectural Projects – Terms, Definitions
- TS 498 Design Values of Loads to be Considered in the Dimensioning of Structural Elements
- TS 1844 Technical Drawings of Structures - Projection Methods
- European Standards, also published as TS EN, can be used in accordance with our country's mandatory regulations and standards.
- TS EN 1990 Principles of Structural Design
- TS EN 1991-1-1 Actions on Structures Part 1-1: General Actions – Densities, self-weights of structures and imposed loads
- TS EN 1991-1-2 Actions on Structures – Part 1-2: General Actions – Effects on structures exposed to fire
- TS EN 1991-1-3 2009 Actions on structures – Part 1-3: General actions, snow loads
- TS EN 1991-1-4 2005 Actions on structures – Part 1-4: General actions, wind actions
- TS EN 1992-1-1 Design of concrete structures – Part 1-1: General rules and rules applicable to buildings
- TS EN 1992-1-2 Design of concrete structures – Part 1-2: Structural fire design
- TS EN 1993-1-1 Design of steel structures – Part 1-1: General rules and rules applicable to buildings
- TS EN 1993-1-2 Design of steel structures – Part 1-2: Structural fire design
- TS EN 1993-1-3 Design of steel structures – Part 1-3: General rules – For cold-formed thin-walled members and sheet metal cladding
- TS EN 1993-1-4 Design of steel structures – Part 1-4: General rules – Additional rules for stainless steel
- TS EN 1993-1-5 Design of steel structures – Part 1-5: General rules – Additional rules for flat plate structures not subject to lateral loads
- TS EN 1994-1-1 Design of composite steel and concrete structures – Part 1-1: General rules and rules applicable to buildings

- TS EN 1994-1-2 Design of composite steel and concrete structures – Part 1-2: Fire design of structures
- TS EN 1997-1 Geotechnical design – Part 2 General rules
- TS EN 1997-2 Geotechnical design – Part 2: Design supported by laboratory tests
- TS EN 1998-1 Design of earthquake-resistant structures – Part 1: General rules, seismic effects and rules for buildings
- TS EN 1998-3 Design of earthquake-resistant structures – Part 3: Assessment and retrofitting of buildings
- TS EN 1998-5 Design of earthquake-resistant structures – Part 5: Foundations, ground support structures and geotechnical aspects

4.2.2. Regulations and Specifications

- The current regulations that must be complied with are listed below.
- TS 498 Loads to be Considered in the Dimensioning of Structural Elements
- TS 500 Rules for the Design and Construction of Reinforced Concrete Structures
- TBDY 2018 Regulation on Buildings to be Constructed in Earthquake Zones
- ÇYTHYE 2016 Rules for the Design and Construction of Steel Structures
- Technical Specifications for Road Bridges (Ministry of Environment and Urbanisation, General Directorate of Highways)
- Principles for the Design of Road and Railway Tunnels and Other Ground Structures Under Seismic Loads
- Principles for the Design of Road and Railway Bridges and Viaducts Under Seismic Loads

4.2.3. Other Standards and Technical Standards

- ACI 318 Building Code Requirements for Structural Concrete
- AASHTO LRFD Bridge Design Specifications
- FHWA Technical Manual for the Design and Construction of Road Tunnels
- UIC 776-1 Loads to be Considered in the Design of Railway Bridges
- ASCE 7 Minimum Design Loads for Buildings and Other Structures
- NFPA 130 National Fire Protection Association
- TSI 2008 Technical Specification for Interoperability
- UIC 505 International Union of Railways

- DIN 4150 Structural Vibration
- FHWA Technical Manual for the Design and Construction of Road Tunnels
- ITA Guidelines
- AFTES Recommendations

4.3. STRUCTURAL DESIGN RULES

4.3.1. Design Service Life

The design life of structures shall be determined by the Authority, taking into account standards such as TS EN 1990, AASHTO LRFD, FHWA, etc. Subject to the condition that inspections and maintenance of the structures are carried out, the minimum design lives specified below are set out in Table 4.1.

Table 4.1 : Design service life.

Tasarım kullanım ömrü kategorisi	Gösterge tasarım kullanım ömrü (yıl)	Örnekler
1	10	Geçici yapılar(1)
2	10 - 25	Değiştirilebilir yapı kısımları, örnek olarak; kren kirişleri, mesnetler
3	15 - 30	Zirai yapılar ve benzerleri
4	50	Binalar ve diğer yaygın yapılar
5	100	Anıt yapılar, köprüler ve inşaat mühendisliği alanına giren diğer yapılar.

(1) Tekrar kullanılabilen yapılar veya tekrar kullanım bakımından ayrılamaz yapı kısımları, geçici olarak kabul edilmez.

4.3.2. Durability

To ensure structures have sufficient durability, the following parameters must be considered in the design:

- The intended or anticipated use of the structure,
- Design dimensions,
- Environmental conditions,
- The composition, properties and performance of materials and products,
- Soil properties,
- The selection of the structural system,
- The form of structural elements and structural detailing,
- Quality of workmanship and level of control,

- Special protective measures,
- Maintenance planned for the designed service life

4.3.3. Geological, Geodetic and Geotechnical Studies

Geological and geotechnical investigation works, carried out in accordance with the Geotechnical Design Specifications and current national standards, for the purpose of determining the physical and mechanical properties of the soil formations constituting the geological profiles along the route, establishing the groundwater level, and conducting geotechnical assessments, etc., to enable the structural design of the structures.

4.3.4. Loads and Load Combinations

4.3.4.1. General

Design Loads;

- The self-weights of structural elements and the dead and live loads acting upon them.
- Structural deformations caused by temperature changes, concrete shrinkage or creep, differential settlement at supports, and the installation of prefabricated elements with geometric errors into hyperstatic systems,
- Dynamic loads caused by earthquakes, the operation of machinery, or explosions resulting from the malfunctioning of equipment installed in machinery rooms.
- Wind and snow loads, railway and road loads, ground pressures, hydrostatic effects, dynamic effects, etc.

For loads and load combinations, regulations and standards published by official bodies in our country shall be taken into account. Loads and load combinations shall primarily be considered in accordance with the principles of TS 498 “Calculated Values of Loads to be Considered in the Dimensioning of Structural Elements”. Where necessary, European Code (Eurocode) 0 “Fundamentals of Structural Design”, European Code (Eurocode) 1 “Actions on Structures”, European Code (Eurocode) 7 “Geotechnical Design”, ASCE 7-16, AASHTO LRFD and UIC 776-2 Specifications shall also be taken into account.

For load combinations, TS 500, the Regulation on Buildings to be Constructed in Earthquake Zones, and the Regulation on the Design, Calculation and Construction Principles of Steel Structures 2016 shall be used. Where necessary, the AASHTO LRFD and UIC 776-2 Specifications shall also be taken into account.

Where elements supporting escalators and moving walkways are used, the loads generated by the equipment shall be taken into account in the calculations.

Structural elements such as floor slabs, beams, columns and foundations, subjected to loads calculated from various electromechanical equipment, platform supports, etc., shall be examined in detail regarding effects such as bending, shear, punching, deflection, etc. These analysed loads shall be added to the structure.

Should there be an increase in calculated loads due to design changes in architectural, electrical, mechanical, etc. disciplines, or due to construction and operational conditions, these increases will be taken into account in the design.

4.3.4.2. Units

- Lengths : mm, m
- Forces : kN, N,
- Stresses : kPa, MPa,
- Moments : kN·m, N·mm,
- Unit weights : kN/m^3
- Masses : kN, tonnes, kg

4.3.4.3. Permanent loads

Loads created by the self-weight of structural elements, as well as by backfill material, floor coverings, roof coverings, insulation materials, plaster and wall materials, balustrades, utility ducts, etc., on buried structures are included within the scope of permanent loads. Permanent loads shall be in accordance with the loads, material dimensions and types specified in architectural, mechanical and electrical-electronic projects, as well as the TS 498 and TS ISO 9194 standards.

No reductions shall be made to permanent loads under any circumstances.

The unit weights of structural elements shall be used as specified below in accordance with TS 498 and TS ISO 9194 standards:

- Unreinforced concrete: 24.0 kN/m^3
- Reinforced concrete: 25.0 kN/m^3
- Steel: 78.5 kN/m^3
- Compacted backfill: 20.0 kN/m^3

4.3.4.4.

With the exception of vehicle loads, pedestrian loads and temporary loads that are not part of the structure are classified as live loads. Unless otherwise specified, the values listed below shall be used as minimum values for this load group.

Table 4.2 : Live loads for stations

Area Definition	Live Loads	
	Uniformly Distributed Load (kN/m^2)	Point Load (kN)
Common Area	5.0 – 7.5	5.0
Private Area	5.0	5.0
Stairs and Landings	5.0 – 7.5	5.0
Plant Rooms	10.0	10.0
Flooring	7.5–10	7.5–10
Water tanks	Loads on water tanks will be assessed in detail.	-
Car parks (accessible by car)	5.0	-
Areas accessible to lorries and other heavy vehicles	Vehicle loads will be assessed in detail	Individual vehicle loads will be assessed in detail

4.3.4.5. Vehicle Loads

Railway Loads

Actual railway loads shall be provided by the vehicle manufacturer.

- Vertical Train Dynamic Loads

Every component of the structure shall be designed/verified for all possible combinations of these loads and forces and shall be capable of withstanding the effects of all load combinations:

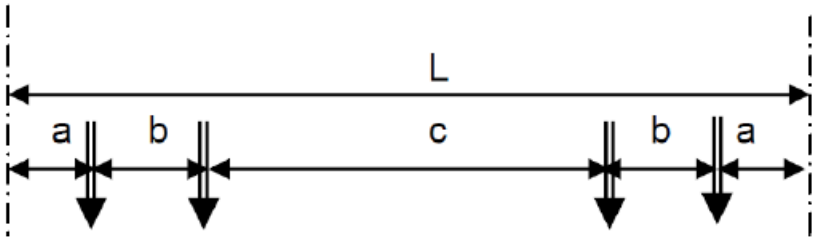


Figure 4.1 : Diagram of vertical train dynamic loads

The following parameters must be taken into account in the design and must be provided by the vehicle manufacturer.

- All axle loads
- Minimum number of carriages in a consecutive arrangement
- L (Length of a wagon – to be approved by the railway vehicle manufacturer)
- a (To be approved by the railway vehicle manufacturer)
- b (To be approved by the railway vehicle manufacturer)
- c (To be approved by the railway vehicle manufacturer)

The maximum number of axles shall be applied to the structure in order to obtain the maximum normal force, maximum shear force and maximum bending moment. The structure shall be suitable for both single-track and (double) two-track line loading conditions.

- Centrifugal forces

The centrifugal force shall be taken at a height of 1.80 m above the top of the rail, acting horizontally and outwards. For certain vehicle types, an increased $h_t$value shall be specified by the authority.

The centrifugal force shall always be combined with the vertical traffic load. The centrifugal force shall not be multiplied by the dynamic coefficients $\Phi_2$or Φ_3.

NOTE: When the vertical effects of the centrifugal force are taken into account, the vertical load effect of the centrifugal force must be increased by the relevant dynamic coefficient after the reduction due to the roll.

- Nose force

The nose force shall be taken as a horizontal force perpendicular to the track centreline. This force shall be applied to both straight and curved sections of track.

The nose force must always be applied in conjunction with the vertical traffic load.

- Traction and braking effects

Acceleration and braking forces act at the top of the rails, in the longitudinal direction of the track. The directions of acceleration and braking forces must be determined according to the permitted traffic directions on each track. Acceleration and braking forces will be considered together with the associated vertical loads. Acceleration and braking forces may be neglected in the ‘empty train’ load model.

- Effects arising from the Nadal theory shall also be taken into account in the design.

Road Loads

The loading conditions specified in the AASHTO specifications and the H30S24 loading specified in the KGM specifications shall be adopted.

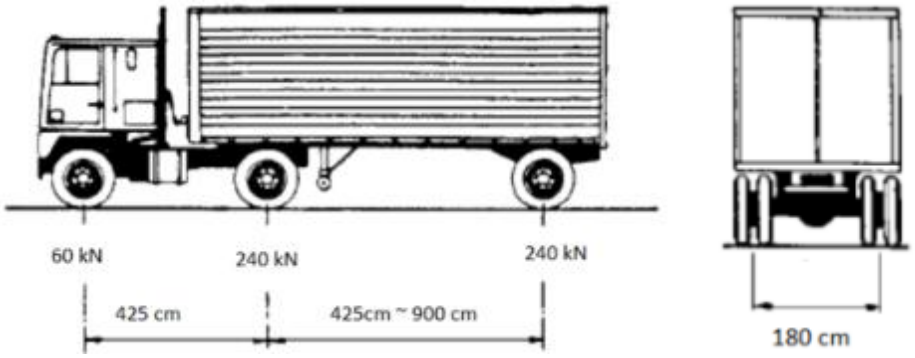


Figure 4.2 : H30-S24 truck load

4.3.4.6. Dynamic Effects

These will be taken into account in accordance with the bridge design specifications and the rules set out in AASHTO LRFD.

4.3.4.7. Temperature Loads

TS 500 shall be taken into account in the analysis and design of all underground and above-ground reinforced concrete structures, and ÇYTHEY-2016 in the design of steel structures. The design shall be carried out taking meteorological temperature data into account.

Expansion and contraction joints shall be designed to prevent cracking of the concrete due to thermal expansion.

4.3.4.8. Wind Loads

TS 498 and the TS EN 1991-1-4 Standard, together with meteorological data, shall be used, taking into account the geometry of the structure.

4.3.4.9. Snow Loads

The snow load shall be determined in accordance with TS EN 1991-1-3, taking into account the structure's geometry, TS 498 and meteorological data. Snow accumulation, etc., shall also be taken into account in the calculations. For these, the relevant TS EN standard or equivalent internationally recognised standards such as ASCE may be used.

4.3.4.10. Seismic Loads

In areas where structures such as stations, truss structures, tunnels and viaducts are located, detailed geological, geophysical and geotechnical studies will be carried out and seismicity parameters will be determined; seismic hazard analyses will be determined through site-specific studies at the locations where the structures are situated.

Site-specific seismic hazard analyses shall be taken into account for all permanent structures in accordance with the criteria specified in TBDY-2018.

The regulations published in the Official Gazette dated 6 October 2020 and numbered 31266 will be taken into account when determining seismic loads. For underground structures, the "Turkish Highway and Railway Tunnels and Other Ground Structures Earthquake Regulation" shall apply; for bridges, the "Turkish Bridge Earthquake Regulation" and the "Turkish Earthquake Regulation for Isolated and Damped Bridges and Viaducts" shall apply; and for above-ground building-type structures, TBDY-2018 shall be taken into account.

For the design of non-structural elements against seismic forces, TBDY-2018 Section 6 shall be taken into account.

4.3.4.11. Shrinkage and Expansion

When determining the dimensions of above-ground structures, in accordance with TS500 Section 6.3.4, for structures exposed to external influences, joint spacing must not exceed 40 m. In frame-type structures protected against temperature changes and lacking rigid walls at their ends, the joint spacing may be increased up to 60 m. These limits may be exceeded provided that calculations are performed taking into account time-dependent behaviour based on internationally recognised standards, or special measures are taken to reduce shrinkage.

The sequence of concrete pouring and the volume of concrete to be poured shall be adjusted in accordance with relevant regulations to minimise shrinkage effects. Furthermore, to prevent shrinkage, it may be recommended to add shrinkage-inhibiting admixtures to the concrete during production or to specify construction details using alternative methods.

4.3.4.12. Construction / Mechanical Equipment Loads

During construction works, the weights of all permanent and temporary materials, as well as the accumulation of materials such as excavated spoil and the movements of machinery, including construction cranes, shall be taken into account. During the construction of temporary structures, a uniformly distributed surcharge load of at least 20 kPa shall be considered, depending on truck and vehicle traffic or the mechanical equipment used in construction.

During construction, if the live loads arising from the construction process are heavier than the live loads considered in the design, they shall be included in the calculations. The dynamic effects of these loads shall also be taken into account.

4.3.4.13. Lateral Soil Loads

Soil Pressures

The calculation of lateral soil effects shall be based on geological parameters and the results of the geotechnical assessment report.

Underground structures and all other retaining structures shall be designed to carry all loads that may act upon them during the construction of temporary works and throughout the service life of permanent works.

In the calculation of static horizontal earth pressures, vertical earth loads, static and dynamic earth pressures, and water pressures acting on structural elements, the design rules specified in TS 498 and TBDY-2018 Section 16 shall be followed. In cases requiring more detailed calculations, internationally recognised standards such as EuroCode 7 and AASHTO LRFD may be used.

In the design of underground structures, loads that may be transmitted to the structure from existing or future buildings will be taken into account in the calculations. The maximum live and dead loads at foundation level will be calculated using parameters such as the foundation level of the adjacent building, the number of storeys and the intended use. The distribution of horizontal and vertical loads to be transferred to the underground structure will be determined based on geotechnical parameters and applied to the relevant structural elements as static and dynamic surcharge loads.

As the walls of the underground stations are supported by the floor at floor level, the pressure coefficients (K_0) and load values corresponding to the static state will be used in the calculation of pressures acting on the walls.

Hydrostatic Effects

Possible changes in groundwater levels shall be taken into account in the design:

- For short-term analysis, the maximum water level observed at the nearest piezometer may be taken into account, considering seasonal variations.
- For long-term analysis, design levels corresponding to minimum and maximum levels will be taken into account. Changes in the groundwater level that may occur during the 100-year service life of the structures will also be taken into account.

New structures must be protected against buoyancy throughout all construction and building phases and during their service life. Where deemed necessary and feasible, drainage systems shall be designed, installed and operated to relieve excessive water pressure forming beneath structures; the structure shall be maintained until it possesses sufficient weight to resist buoyancy with the required minimum safety factor.

Static Soil Pressures

In the calculation of lateral soil loads on underground structures, K_0, $\sigma_z$and $\sigma_s$shall be used to calculate the lateral soil loads acting on the walls.

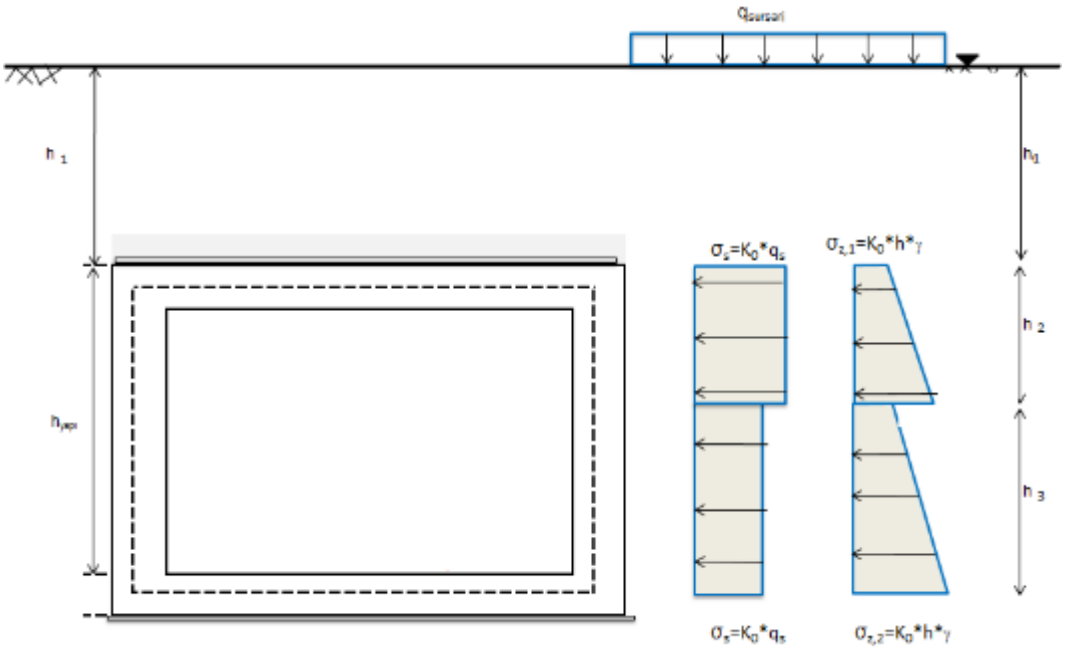


Figure 4.3 : Schematic of lateral earth pressure and surcharge loads on the ground above the GWL

Soil loads shall be applied as follows.

$\sigma_{z,(1;2)}$ $=K_0 . H . \gamma$ (Earth pressure of the soil remaining on the GWL in a state of rest)

$\sigma_{z,1}$ $=K_0 .(\gamma - \gamma_w).H$ (The earth pressure at rest of the soil remaining below the GWL)

σ_w $=\gamma_w .H$ (Hydrostatic pressure of water)

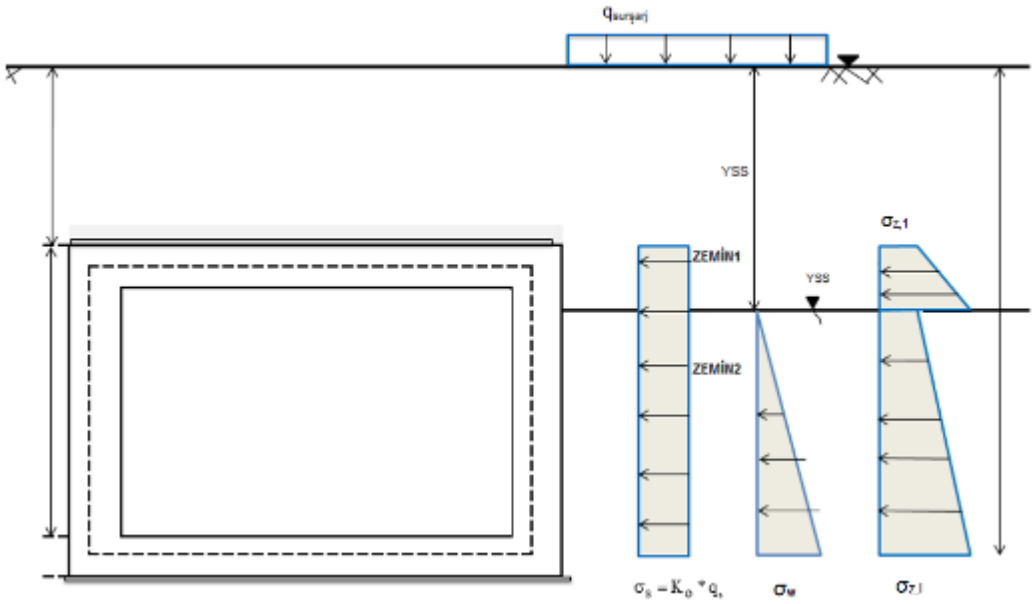


Figure 4.4 : Schematic diagram of lateral soil and surcharge loads on the ground, with the GWL structure remaining above ground level

This load comprises the loads acting from the ground onto the structure in the sections where the structure is embedded in the ground. The unit weights of the soil provided in the ground investigation report will be used in the calculation of these loads. The loads will be applied separately to the right and left side sections according to the architectural design.

Unbalanced Soil Loads

The unbalanced loading condition will be taken into account in the calculation to account for the unbalanced horizontal load conditions to which buried structures may be exposed due to future excavations. The scenario of excavation being carried out on one side of the station will be considered.

When determining the unbalanced loading condition, the location of the project and the surrounding conditions will be taken into account.

Additional load (surcharge load): Road traffic load

All underground structures may be exposed to road traffic loads, as well as potential changes in usage on the pavement surface and in adjacent areas, either during the construction phase or throughout the 100-year design life of the structure.

During the design of all station buildings, road traffic loads shall be taken into account and included in the calculations, whether or not they are included in the existing architectural design.

The static surcharge effects that road traffic loads will exert on the retaining walls of underground structures, as well as the dynamic surcharge loads that will occur during an earthquake, shall be calculated and applied to the relevant structural elements.

Loads shall be applied according to the most unfavourable combination and included in the calculation by multiplying by a specific factor.

In the calculation of road live loads affecting underground structures located beneath roads, streets and pavements, the H30-S24 Standard Truck Load specified in the Technical Specifications for Road Bridges or an equivalent load shall be used as the basis. Detailed design may be carried out in accordance with the AASHTO LRFD Bridge Design Specifications (Bridge Design Specifications) also published by the General Directorate of Highways.

Additional Loads (Surcharge Loads): Building Loads

Attention shall be paid to additional surcharge loads arising from existing buildings and new structures (bridges, monuments, buildings, residential properties, railway systems, etc.). These loads shall be assessed separately for each building or structure and taken into account in the analysis of permanent and temporary underground structures, in accordance with the foundation type and layout of each building/structure.

Overload effects resulting from live and dead loads created by new structures in the vicinity of existing buildings or construction sites will be calculated, or load data will be determined from the relevant existing or new construction project in the vicinity. With regard to permanent structures, potential surcharge loads from future buildings, taking into account town planning schemes throughout the project's lifespan, will also be considered; these loads will be assessed based on data obtained from the relevant authorities.

In existing structures, whether structural or non-structural (architectural elements and functional aspects) damage has occurred will be reported in accordance with the rules specified in the Building Risk Analysis section.

The effects of any potential asymmetric additional load on the underground structure (station, tunnel, shaft, etc.) will be taken into account in the analyses. In the calculations, a situation where there is an additional load from the structure on one side of the underground structure but not on the other will be assessed as the most unfavourable condition.

4.3.4.14. Load Combinations

Designs will be carried out in accordance with the load combinations specified in TS500, ÇYTHEY-2016, TBDY2018, AASHTO LRFD and the Bridge Design Specifications, depending on the type of structure.

4.3.4.15. Crack Control

Cracks of a width that could cause corrosion of the reinforcement in the structure shall not be permitted. The crack limits specified in TS500 shall be adhered to.

5. RAILWAY SECTION DESIGN

5.1. INFRASTRUCTURE

In the infrastructure design, local geological and hydraulic characteristics will be taken into account, and measures will be taken to ensure that rainwater and floodwater are channelled in such a way as not to affect the facility.

5.1.1. Infrastructure Design

It is envisaged that the “UIC Code 719”, prepared by the International Union of Railways, will be utilised to determine the thicknesses of the superstructure to be used on railways. The thicknesses of the ballast, sub-ballast and prepared subgrade are calculated by evaluating the parameters outlined below in conjunction.

5.1.1.1. Ballast – Sub-Ballast Minimum Thickness Calculation

In calculating the thicknesses (e) of “ballast” and “sub-ballast”, which form the core of the track structure design, the following parameters are taken into account: the bearing capacity of the subgrade (E), UIC groups (a), sleeper length (b), UIC groups (c) in conjunction with operating conditions, axle load (d), and train speed-subgrade bearing capacity (f) and geotextile (g) parameters are taken into account. The ballast and sub-ballast thickness calculation as specified in the UIC standard is provided below.

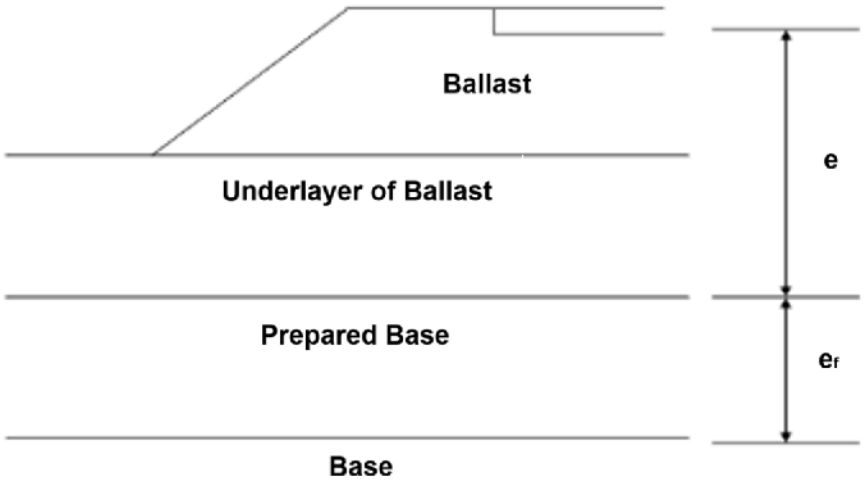


Figure 5.1 : Rail System Infrastructure Layers

* E = 0.70 m P1: weak subgrade (1)

E = 0.55 m P2: average subgrade (1)

E = 0.45 m P3: good foundation (1)

* a = 0.00 IRS Group 1 and 2 or vehicles with a speed exceeding 160 km/h

a = -0.05 m IRS Groups 3 and 4

a = -0.10 m IRS Groups 5, 6, 7, 8 and 9 “passenger” (2)

a = -0.15 m UIC Groups 7, 8 and 9 “unoccupied” (2)

* b = 0 wooden sleeper L = 2.60 m

b = (2.50 – L) / 2 concrete sleeper (L, b in metres)

If L > 2.50 m, the value of b will be negative

* c = 0.00 standard dimensions

c = -0.10 m Under heavy operating conditions on existing lines, for UIC groups

7, 8, 9 (unmanned)

c = -0.15 m on existing lines under severe operating conditions, for Groups

7, 8, 9 (non-passenger)

* d = 0.00 Maximum axle load of loaded vehicle < 200 kN d = + 0.05 loaded vehicle maximum axle load < 225 kN d = + 0.12 Maximum axle load of loaded vehicle < 250 kN

* f = 0 V ≤ 160 km/h or high-speed trains on P3 track bed

f = +0.05 High-speed trains with track bed P2

f = +0.10 High-speed trains with a track bed of P1

* g = + If the sub-base material is QS1 or QS2, geotextile will be used in the superstructure.

g = 0 If the prepared subgrade is QS3, geotextile is not required

Notes:

- Bearing capacity classes are explained in Table 5.1.
- UIC groups are defined in UIC Publication 714.

5.1.1.2. Determination of the Prepared Subgrade Thickness (ef)

In order for the subgrade, consisting of the subgrade classes defined in the UIC specifications and the fill material, to achieve the required bearing capacity, it must be reinforced with a layer of graded material. In this context, the minimum thickness of the 'prepared subgrade' is determined by jointly evaluating the factors relating to the subgrade, the quality of the graded material, and the required bearing capacity class for the subgrade. Alternative design combinations are provided in Table 5.1.

Table 5.1 : Determination of Subgrade Bearing Capacity

Subgrade	Required bearing capacity class for the subgrade	Prepared Subgrade Property	
		Material Class	**Minimum Thickness (m)**
QS1	P1 P2 P2 P3	QS1 QS2 QS3 QS3	- 0.50 0.35 0.50
QS2	P2 P3	QS2 QS3	- 0.35
QS3	P3	QS3	-

5.2. SUPERSTRUCTURE

The rails upon which the vehicles run, the fastening materials connecting these to the sleepers or the reinforced concrete sub-rails and to one another, the sleepers and ballast, or the sub-rails and the first-phase ballast concrete, shall constitute the superstructure.

The superstructure shall be designed to safely fulfil the following functions:

- There shall be no permanent deformation due to the effects of static and dynamic forces at the maximum vehicle load and maximum speed specified in the project,
- Track dimensions and vehicle dimensions shall be compatible with one another to ensure safe running at the desired speed and within accepted wear limits,
- The curve radius shall be kept large enough not to limit the system's maximum speed,

- Curves shall be designed such that, when the permitted speed is reached, the forces, lateral acceleration and its variation over time are minimised. Where necessary, transition curves, transition ramps and transition curves shall be used,
- Surface water will be easily drained from the superstructure.

There are two construction types for standard rail system superstructures: ballasted and ballastless.

5.2.1. Ballastless Track

A ballastless track may consist of rails connected directly to the sub-structure via fastening materials, connected to prefabricated concrete sleepers resting on an elastic base in single or double blocks, or connected to prefabricated slabs.

The track will be fixed directly to the concrete track bed using embedded anchor bolts/rods. The design capacity will be ensured between the tunnel lining and the sub-track beam. A transition zone and/or approach plates will be designed between the directly fixed track and the ballasted track.

In ballastless tracks, necessary measures will be taken to ensure rail track flexibility and to reduce vibration and noise; an elastic material will be used between the concrete and the rail foundation.

5.2.2. Ballasted Track

A ballasted track is a track where rails are mounted on concrete or timber sleepers set into aggregate that meets the ballast definition and has been properly levelled.

Vibration and noise insulation will be provided in the necessary sections of the track.

5.3. MANOEUVRE AND PARKING TRACK

The Shunting and Stabling Track is the section of track located outside the signalled main line, not used for passenger transport, and situated within the defined boundaries of the shunting and stabling area.

5.4. ACCESS ROADS ON FULLY PROTECTED TRACK

Access routes will be designed at appropriate intervals to allow necessary equipment to access the track from the road in the event of an emergency.

5.5. RAILS

5.5.1. Types of Rail

Rails shall be of 60E1 or 60E2 profile, as determined by the approved track design, and shall be manufactured from R260 grade steel. Rails shall comply with TS EN 13674-1 Railway Applications – Track – Rail – Part 1: Vignole Railway Rails 46 kg/m and Above (Railway Applications – Track – Rail – Part 1: 60.21 kg/m and Above Vignole Railway Rails) and the applicable requirements of the relevant UIC standards

In curved sections, rails of R350HT quality with hardened heads may be used. Furthermore, in recognition of good practice for resilience and reduced wear, the use of heat-treated R350HT grade rail shall be considered as the preferred option not only in curved sections but also in areas subject to high axle loads, steep gradients, or frequent braking, such as station approach zones and depot connections. Contractor shall justify in the design submission any decision to revert to R260 grade in such locations.

Where grooved rails are required, rail profiles compliant with the TS EN 14811 – Railway applications – Track – Special purpose rail – Grooved rails and associated construction profiles standard shall be used.

All rails in service shall be manufactured, installed, inspected and tested in accordance with the requirements of the latest versions of UIC Standards or equivalent standards. All cutting and splicing of rails shall comply with the requirements of UIC Standards or equivalent standards. Rails shall be welded and kept as long as possible.

No holes shall be drilled in the rails.

The rail gradient shall be 1/40 inwards, except for special track sections where the gradient is zero or less to comply with design details.

Rails intended for use on curves with a radius of 150 m or less shall be pre-bent or pre-curved using standard workshop methods or other approved methods.

5.5.2. Tolerances

All track and track equipment components shall be installed in accordance with the minimum tolerances that comply with track construction tolerances, which account for temperature variations and ensure construction accuracy.

Track construction and installation tolerances shall comply with the requirements of the applicable TSI, EN 13848 series, relevant UIC recommendations and the tolerances specified herein. Where a conflict exists, the more stringent requirement shall apply. The tolerances

specified below represent maximum permitted construction deviations at the time of acceptance.

Table 5.2 : Line construction tolerances

	MAIN LINE	IN THE DEPOT
Along the Track	3 mm between rail centres over a 16 m rail length	For 20 m of track, 3 mm between rail centres
Track Gauge	1435 mm ± 3 mm	1435 mm ± 3 mm
Longitudinal Grade	± 3 mm over 50 m	± 10 mm per 50 m
Transverse Level Difference	± 2 mm	± 3 mm

5.5.3. Counter Rails

Guard rails and check rails shall be provided where required by the applicable standards, turnout design requirements, derailment containment requirements, bridge and viaduct protection requirements, or specific track alignment characteristics.

The design, manufacture and installation of guard rails, check rails and associated components shall comply with the relevant requirements of the EN 13232 series and applicable UIC recommendations.

Where required for bridges, viaducts, special structures or other locations identified through the design process, guard rails shall be provided to reduce the consequences of derailment and protect critical infrastructure assets.

5.6. SWITCHES

The design, manufacture, installation and maintenance of Switches and Crossings (S&C) for the High-Speed Railway system shall comply with the relevant European Standards, interoperability requirements and internationally accepted railway engineering practices applicable to high-speed operation.

In the tender design, a total of 24 turnouts of 1/24 R = 1500 m, 6 turnouts of 1/18.5 with R = 1200 m, 10 turnouts of 1/12 with R = 500 m, and 1 turnout of 1/9 with R = 300 m have been used.

The switches shall be designed to ensure safe, reliable and smooth train operation under the specified operational speeds, axle loads and traffic conditions. Particular attention shall be given to ride comfort, wheel–rail interaction, dynamic behaviour, maintainability and lifecycle performance.

High-speed switches located on main running lines shall generally utilize long-radius geometries with low crossing angles in order to minimize lateral acceleration and dynamic impact forces during diverging movements. Turnout geometry shall be compatible with the line speed, operational concept and signaling system requirements.

Movable frog (swing nose crossing) technology shall be considered where required to reduce wheel impact loads, vibration and maintenance requirements, particularly for diverging routes with elevated operational speeds.

The switch design shall include: switch rails, stock rails, crossing panels, check rails / guard rails, where required, fastening systems, bearers/sleepers, actuation and locking equipment, detection systems, drainage arrangements, cable routing provisions, maintenance access requirements.

All S&C components shall be designed to withstand the operational and environmental conditions of the project, including dynamic loading, thermal stresses, fatigue effects and vibration induced forces.

Rail sections used within the turnout system shall be compatible with the adjacent plain line track system. Rail steel grades shall be selected according to traffic intensity, axle load, operational speed and wear conditions. Heat-treated rail grades may be required in high wear locations and curved sections.

Where local climatic conditions so require, all special track equipment shall be fitted with heating elements to prevent ice formation from obstructing the movement of the switches.

Switch systems shall be designed to provide adequate protection against derailment and excessive wheel unloading. Wheel guidance through crossings shall be ensured by appropriate crossing geometry and check rail arrangements where applicable.

The switch layout and geometry shall be coordinated with the track alignment design, superelevation configuration and transition curve arrangement in accordance with the overall railway geometric design criteria.

Construction tolerances, installation tolerances and acceptance criteria for switches shall comply with the relevant European Standards and project-specific technical requirements.

The design and construction of the turnout systems shall comply with the latest editions of the following standards, where applicable:

EN 13232 series — Railway applications — Track — Switches and crossings

EN 13232-1: Definitions

EN 13232-2: Requirements for geometric design

EN 13232-3: Requirements for wheel/rail interaction

EN 13232-4: Actuation, locking and detection

EN 13232-5: Switches

EN 13232-6: Fixed common and obtuse crossings

EN 13232-7: Crossings with moveable parts

EN 13232-9: Layouts

EN 13803 series — Track alignment design parameters

EN 13848 series — Track geometry quality

EN 13231 series — Track acceptance works

EN 13674 series — Railway rails

EN 14363 — Testing and simulation for running characteristics of railway vehicles

EN 13481 series — Performance requirements for fastening systems

EN 13146 series — Test methods for fastening systems

Where project-specific requirements impose stricter criteria than the referenced standards, the more stringent requirements shall govern.

The types of switches will be determined by the designer.

5.7. FASTENING ELEMENTS

Fastening elements shall comply with the specifications set out in the following standards:

TS EN 13481-1: Railway Applications – Railway – Performance Characteristics for Fastening Systems – Part 1: Definitions

TS EN 13481-2: Railway Applications – Railway – Performance Characteristics for Fastening Systems – Part 2: Fastening Systems for Concrete Sleepers

TS EN 13481-3: Railway Applications – Railway – Performance Characteristics for Fastening Systems – Part 3: Fastening Systems for Timber Sleepers

In addition to the above standards, fastening systems shall be of a high-performance elastic type providing appropriate dynamic stiffness, fatigue resistance, electrical insulation, durability and pull-out resistance characteristics suitable for the full range of operating and environmental conditions. Fastening systems shall comply with the applicable requirements of the relevant EN standards and shall demonstrate proven performance in railway applications

The Contractor shall submit technical data sheets and independent test results demonstrating compliance with the specified performance requirements as part of the design approval process.

5.7.1. Directly Fixed Rail Connections

Rail fastenings shall provide resistance against loads arising from vehicle wheel loads, rail expansion and the structures on which the rail is supported.

In directly fixed track sections, the entire flexibility of the track will be provided by flexible rail pads or other physical measures taken in the superstructure. The characteristics of the fastenings will be explained in the following points.

a) Rail Head Lateral Deflection

The rail fastening system shall be designed to provide adequate lateral restraint of the rail under all operational loading conditions applicable to the Project, including passenger trains, freight trains, maintenance vehicles, thermal forces, traction and braking forces, and the dynamic effects arising from track curvature.

Under the governing combination of vertical and lateral loads, the fastening system shall limit the lateral displacement of the rail head such that the resulting opening between the rail and the fastening assembly does not exceed 6 mm.

The design shall consider the most adverse operating conditions, including cant deficiency, centrifugal forces, wheel-rail interaction forces and thermal actions. Compliance shall be demonstrated through calculation, testing and manufacturer-certified performance data in accordance with the relevant requirements of the TS EN 13146 and TS EN 13481 series.

The maximum value of the normal centrifugal force shall be determined by the ride comfort criterion (see Table 3.4).

b) Vertical Deflection of the Rail

The rail fastening system shall provide sufficient vertical elasticity to ensure appropriate load distribution, ride quality and durability of the track system.

At a reference temperature of 20°C, the dynamic vertical rail deflection at the rail seat shall be:

- not less than 0.65 mm under the normal design passenger train loading condition;
- not greater than 1.8 mm under the governing design loading condition, including the most adverse passenger, freight and maintenance vehicle loading applicable to the Project.

The Contractor shall demonstrate compliance through calculations and test data in accordance with the relevant requirements of the TS EN 13146 and TS EN 13481 series.

c) Longitudinal Restriction

The rail fastening system shall provide longitudinal rail restraint appropriate to the operational, thermal and structural requirements of the Project. The required performance shall be demonstrated by testing in accordance with TS EN 13146-1. The minimum longitudinal rail restraint shall not be less than 9 kN per rail seat unless otherwise justified by the Contractor and approved by the Engineer.

d) Gap Resulting from Fracture

The longitudinal resistance provided by the fastening element shall be of a magnitude such that the calculated opening gap at minimum rail temperature is less than 50 mm. In calculating this opening, the amount of slip of the rail within the fastening arrangement and the deformation of the viaduct structure shall be taken into account.

e) Fastener Spacing

Unless otherwise specified in the detailed design, in directly fixed track sections, the spacing of fasteners shall not exceed 0.650 m on curved tracks, 0.750 m on straight tracks, and 1.0 m on workshop tracks.

f) Electrical Insulation Properties

It is a requirement that the rails are electrically insulated from the track infrastructure for all rail fastenings outside the depot.

5.7.2. Concrete Sleeper Connection Components

The rail fastening components to be used in conjunction with the rail fastening system on concrete sleepers will be similar to those specified for directly fixed track sections.

5.8. SLEEPERS

5.8.1. Prestressed Concrete Sleepers

Area of Use: Prestressed concrete sleepers shall be used on all at-grade tracks and ballasted bridges.

Spacing: Prestressed concrete sleepers shall be installed at a maximum spacing of 75 cm centre-to-centre, depending on axle load and speed. Spacing may vary in special cases.

Dimensions: Concrete sleepers shall comply with the dimensions and characteristics specified in the following standards:

TS EN 13230-1: Railway Applications – Railway – Concrete Sleepers and Supports – Part 1: General Rules

TS EN 13230-2: Railway Applications – Railway – Concrete Sleepers and Supports – Part 2: Prestressed Monolithic Sleepers

TS EN 13230-3: Railway Applications – Railway – Concrete Sleepers and Supports – Part 3: Reinforced Twin Sleepers

TS EN 13230-4: Railway Applications – Railway – Concrete Sleepers and Supports – Part 4: Prestressed Sleepers for Switches and Crossings

Sleepers of Special Dimensions (in terms of length): Due to electrical or structural requirements within the system, sleepers of special dimensions may be used.

5.8.2. Wooden Sleepers

Area of Use: These shall only be used in sections of the track where specific requirements apply. Wooden sleepers shall not be used within tunnels, enclosed structures, underground stations, or within 50 metres of tunnel portals, where fire safety requirements demand the use of non-combustible materials. In such locations, prestressed concrete sleepers or equivalent non-combustible alternatives shall be used exclusively. Where ballastless track is provided in underground sections, the sleeper or support element material shall achieve at minimum Fire Resistance Class A1 in accordance with applicable EN standards. The use of all wooden sleepers shall comply with the TS 700 EN 13145 Standard – Railway Applications – Railway – Wooden Sleepers and Supports and TCDD Specifications.

Dimensions: Standard wooden sleepers used on ballasted tracks shall comply with the dimensions and specifications set out in the TS 700 EN 13145 Standard; furthermore, both edges shall be wrapped with steel strips and/or the sleeper ends shall be fitted with stainless steel rectangular or S-shaped spikes driven perpendicular to the sleeper.

Spacing: Wooden sleepers shall be laid at intervals of up to 60 cm centre-to-centre, depending on the axle load and speed.

Scissor Crossbeams: These are crossbeams of varying lengths used in specific situations, and their dimensions will vary depending on their position.

5.9. BALLAST

In rail systems, this is a material laid on the track bed that distributes the load from the sleepers to the ground, prevents vertical deformation, maintains the specified geometric shape by preventing horizontal movement in the track plane, and provides drainage. The granulometric properties of the ballast to be used shall comply with Table 5.3.

Type to be used: Crushed stone ballast will be used.

Table 5.3 : Ballast granulometric properties

SIEVE APERTURE		PERCENTAGE OF MATERIAL PASSING THROUGH THE SIEVE
(inches)	(mm)	(%)
3"	76.2	100
2 ½"	63.5	90–100
1½"	38.10	20–55
¾"	19.05	0–15
½"	12.70	0–5
No. 200 sieve		0-1

Ballast Depth: Ballast depth is defined as the vertical distance between the upper surface of the sub-ballast (if present) or, if there is no sub-ballast, the upper surface of the track bed, and the underside of the sleeper. Although the depth varies depending on the track bed and ground conditions, it shall be at least 30 cm.

Ballast Width: The ballast width shall be determined by adding 20 cm from the end of the sleeper on curved tracks with R > 300 m, and 30 cm on curved tracks with R < 300 m.

Ballast Material: The material to be used as ballast shall be of basalt, granite, diorite, diabase or quartzite origin. Slag, limestone, sandstone and all types of claystone shall not be used. The materials shall comply with TS 7043 EN 13450/A – Standard for Aggregates for Railway Ballast.

Ballast Conductivity: When selecting ballast material from alternative options, the material with the lowest electrical conductivity—measured in both dry and wet conditions—shall be chosen to minimise stray currents.

Ballast Size Ratio: The ratio of the longest dimension to the shortest dimension shall not exceed 3. However, it is important that the rock types specified above, to be used as ballast, do not exhibit weathering. Petrographic analysis will be used to ensure that the rock material to be used is fresh.

Sub-base Course: A sub-base course shall be used for cohesive soils with insufficient bearing capacity. It shall be arranged in single or multiple layers. It may consist of granular materials such as sand or gravel, or a non-compressible synthetic geotextile material. The thickness of the sub-ballast layer shall be a minimum of 15 cm. This thickness shall be determined according to ground conditions, and a suitable gradient shall be provided for drainage.

5.10. RAILWAY STRUCTURES

5.10.1. At-Grade Lines

At-grade line;

- A complete drainage system connected to the existing rainwater drainage channel,
- A pedestrian walkway,
- Uninterrupted cable route,
- Traverses and ballast with necessary transition elements,
- Noise barriers on both sides of at-grade lines passing through residential areas where required,
- A safety barrier between the road and the line in areas close to road infrastructure,
- On both sides of the track, safety barriers will be installed to prevent unauthorised persons from entering the track (the barriers will be of a non-climbable type, 2,0 m high from the highest point or kerb, with the top section consisting of standard galvanised barbed wire).

Examples of at-grade and cut-and-fill cross-sections related to the line route are shown at Figure 5.2, Figure 5.3, Figure 5.4, Figure 5.5 and Figure 5.6.

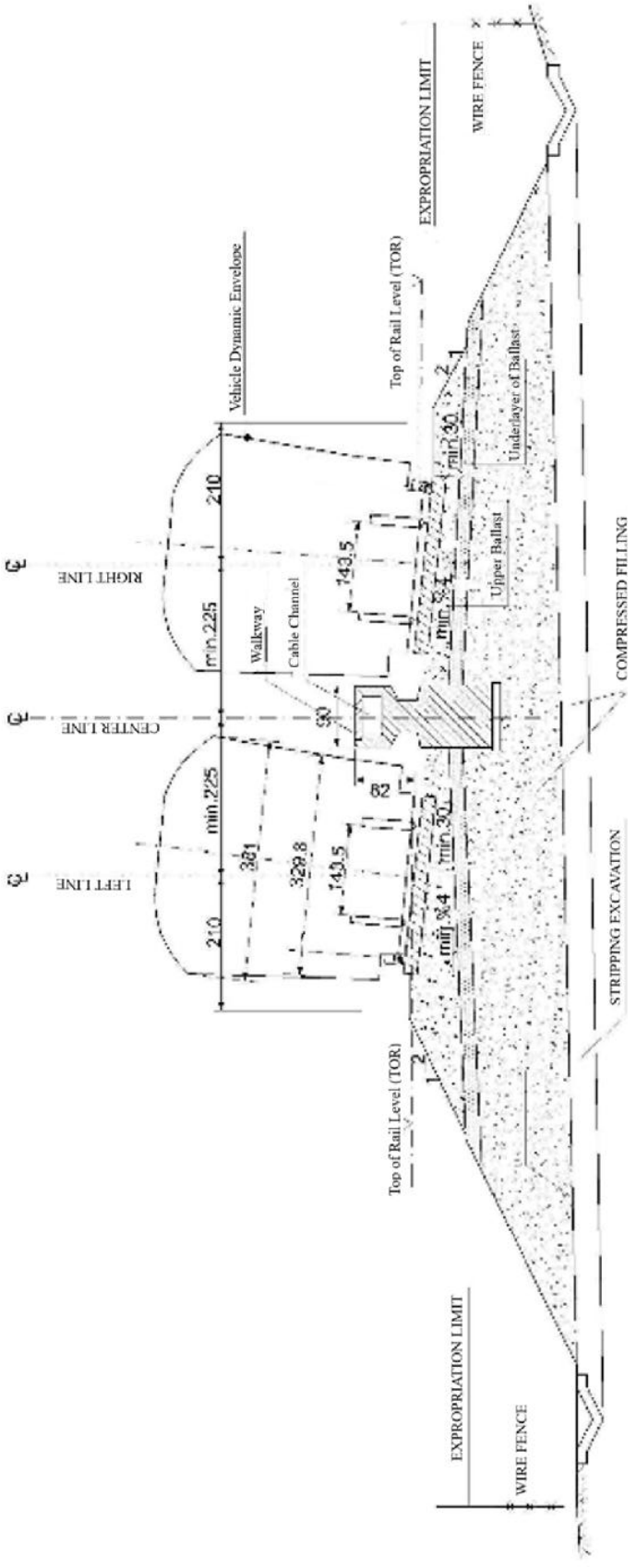


Figure 5.2 : At-grade track cross-section – embankment – curve (example)

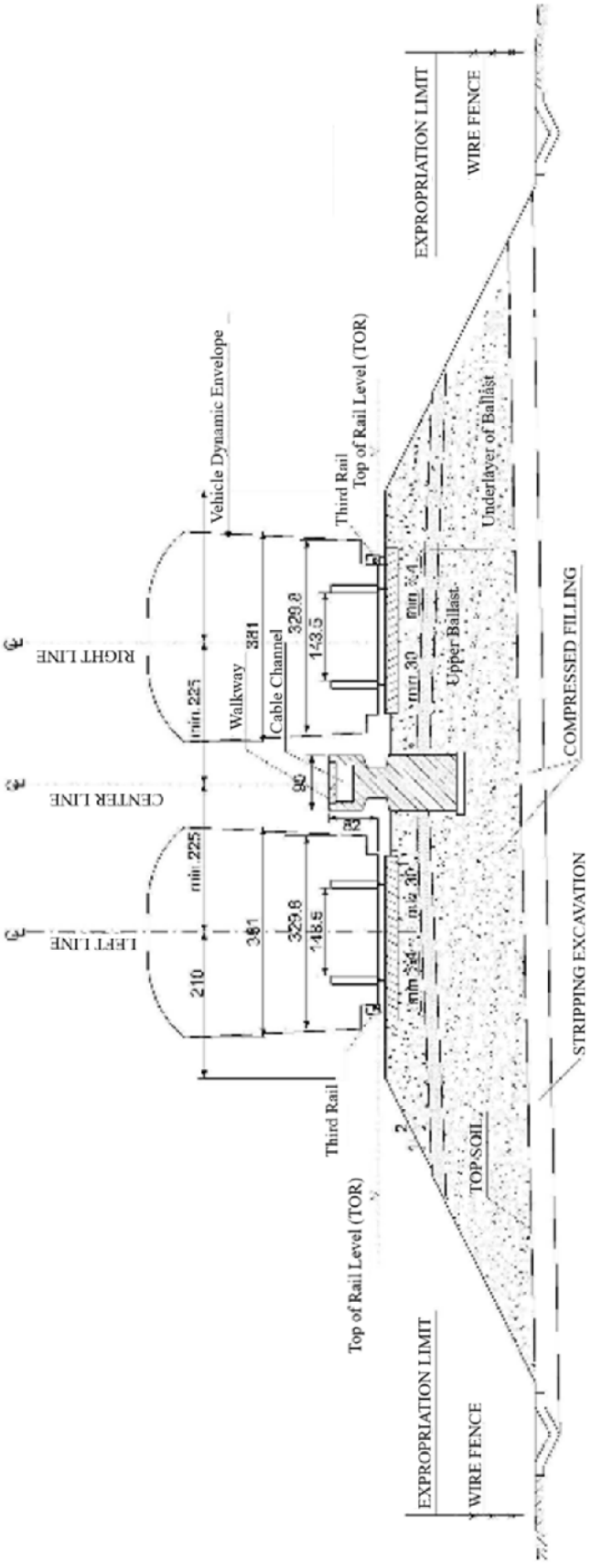


Figure 5.3 : At-grade track cross-section – in embankment – on a slope (example)

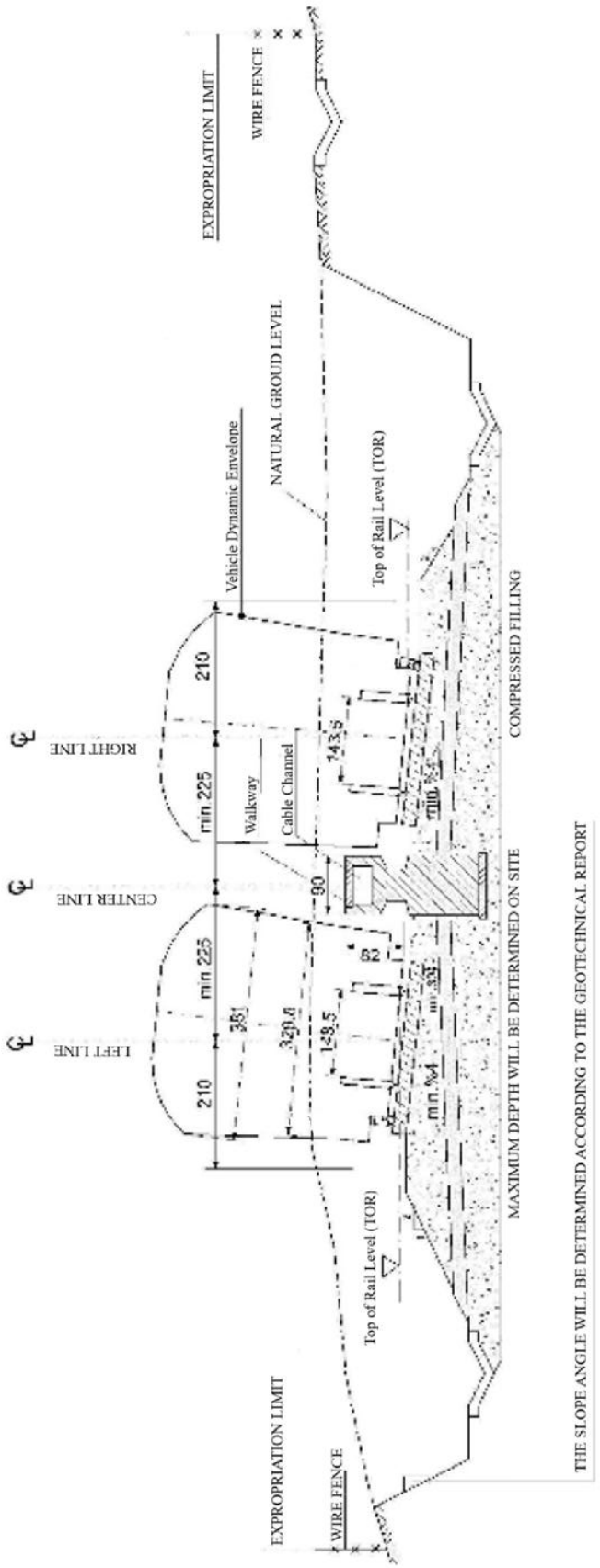


Figure 5.4 : At-grade track cross-section – on embankment – in a curve (example)

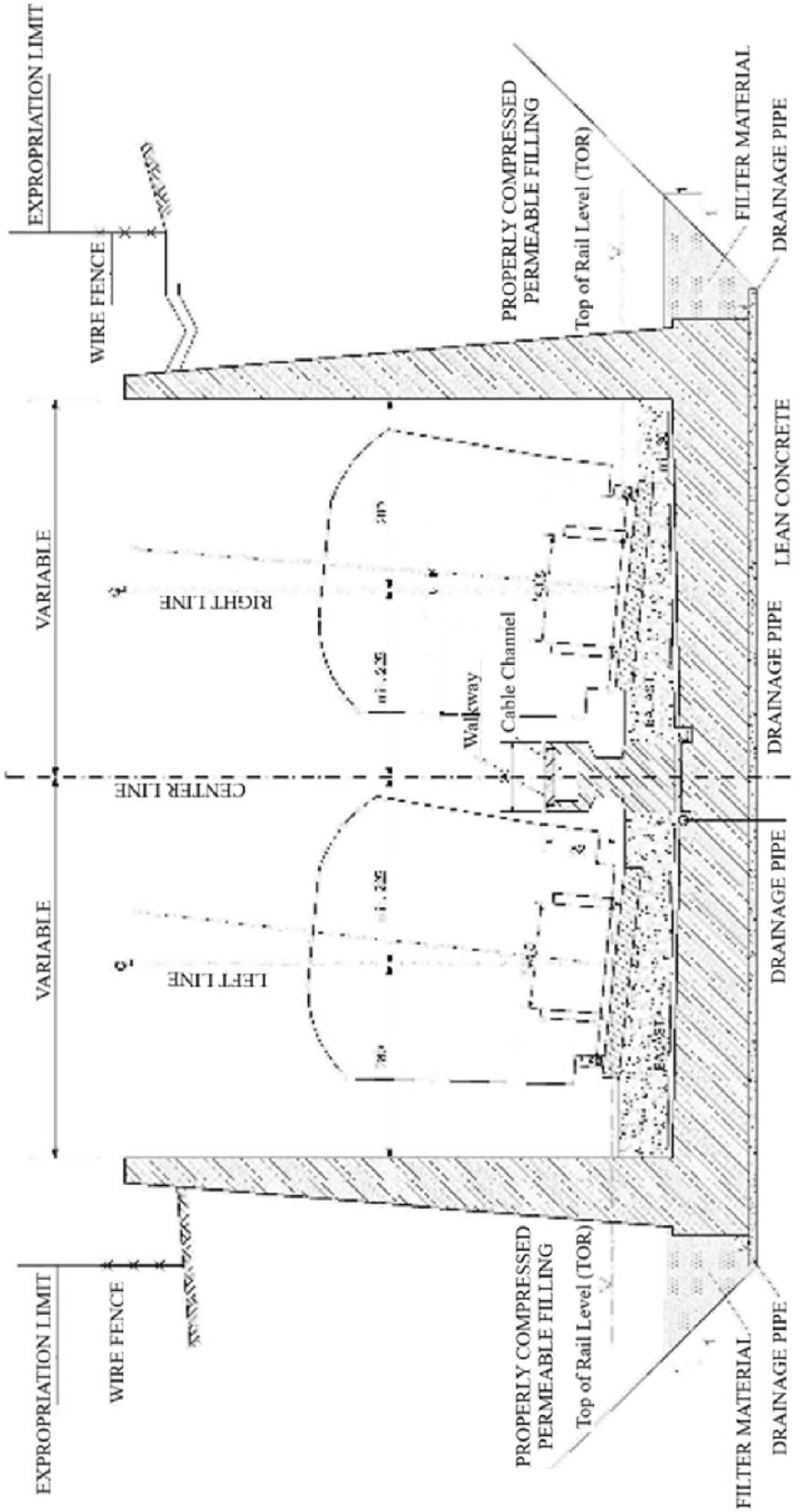


Figure 5.5 : Cut track cross-section – retaining wall – curve (example)

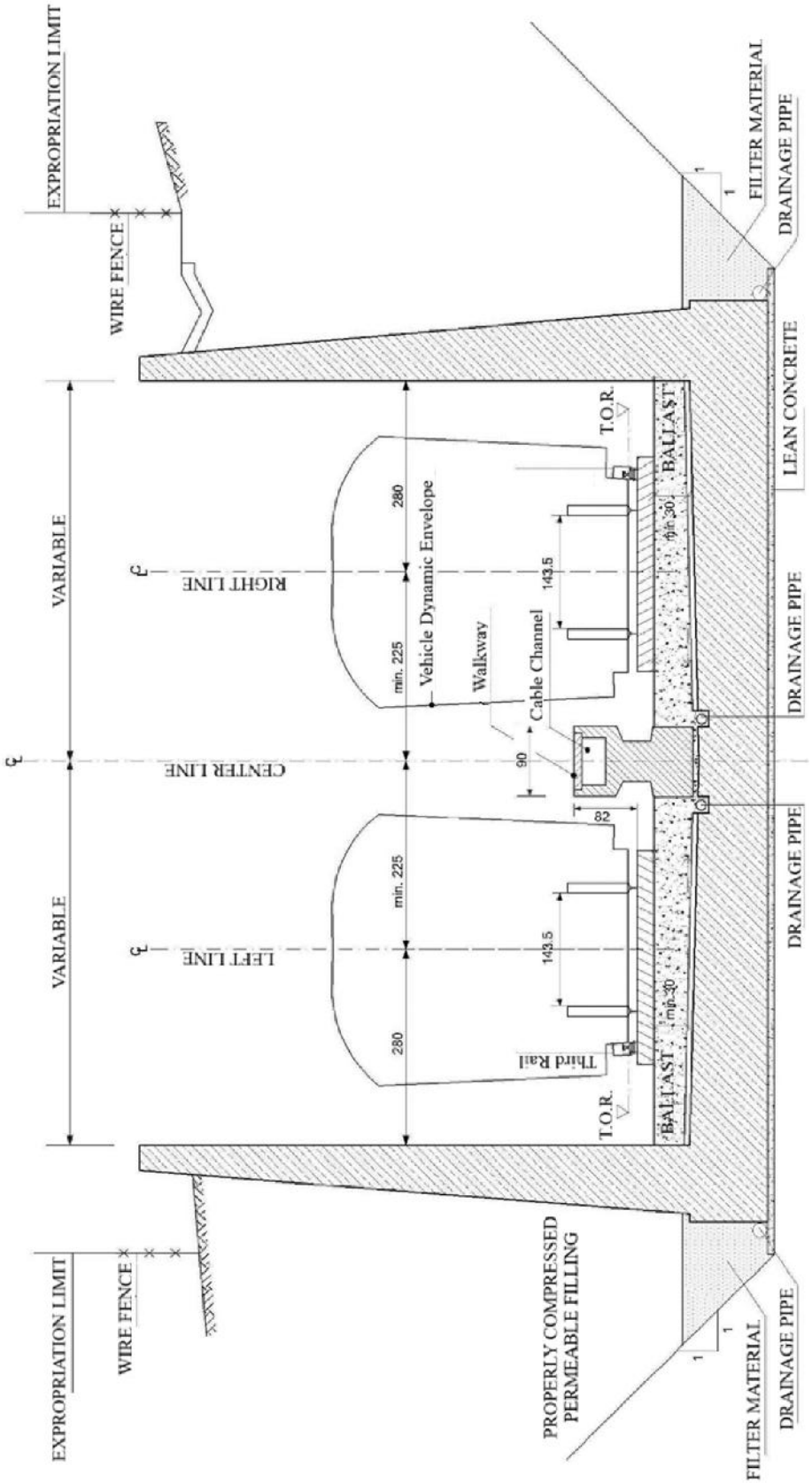


Figure 5.6 : Cut track cross-section – retaining wall – embankment (example)

Elevated Lines An example of an elevated line Figure 5.7, Figure 5.8 and Figure 5.9 are shown.

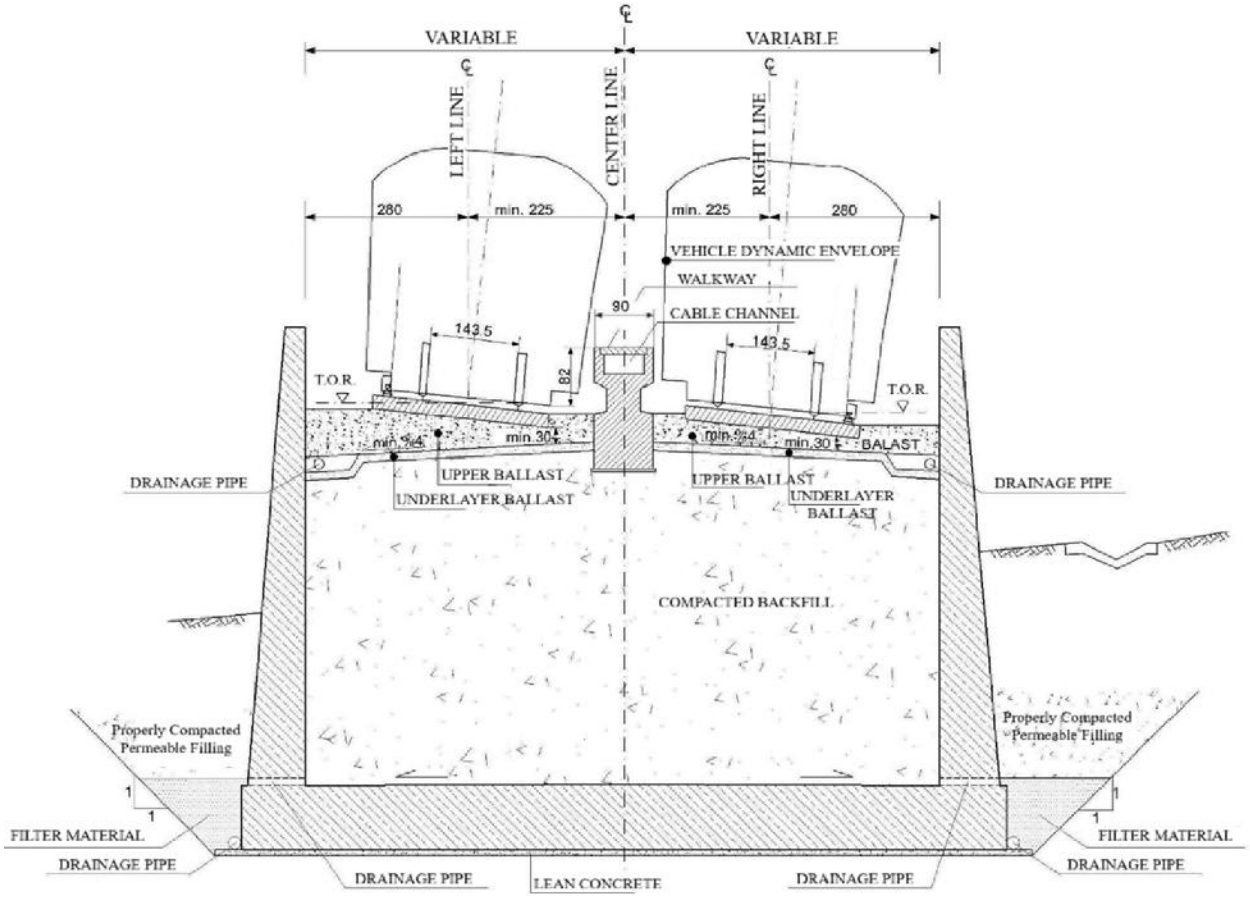


Figure 5.7 : Elevated track cross-section – retaining wall – curve (example)

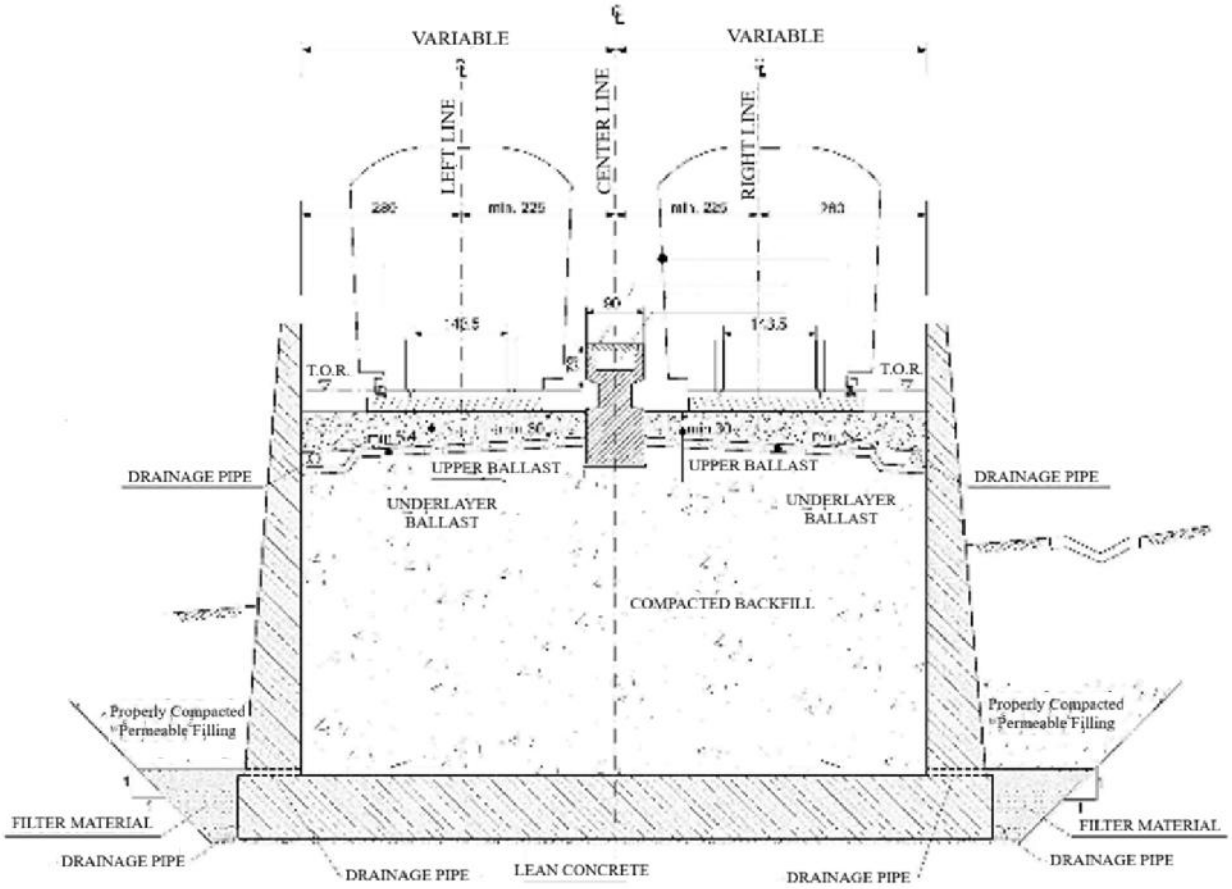


Figure 5.8 : Elevated track cross-section – retaining wall – embankment (example)

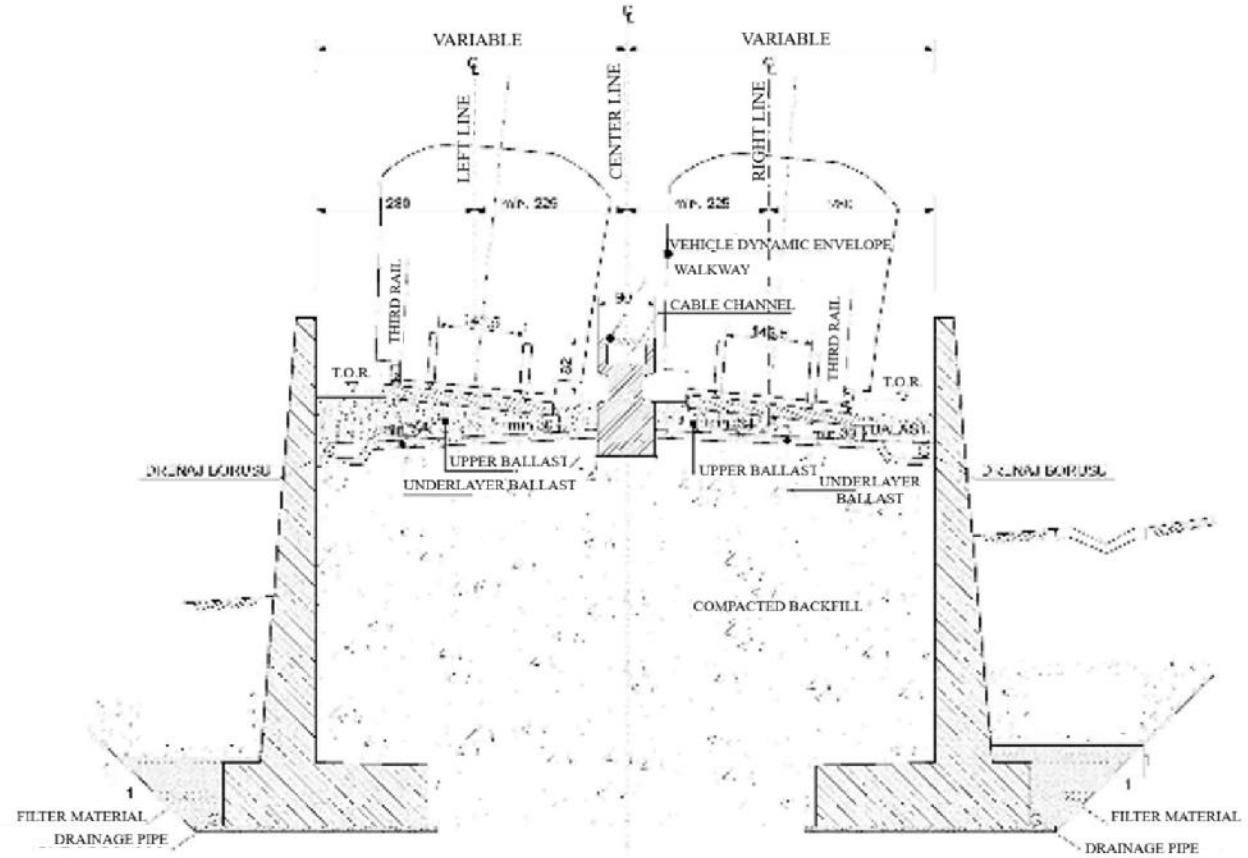


Figure 5.9 : Elevated track cross-section – retaining wall – curve (example)

5.11. RETAINING STRUCTURES

See Principles of Geotechnical Design Technical Specification

5.12. EARTHWORKS

5.12.1. Tunnels

5.12.1.1. General

The following principles shall be taken into account in tunnel calculations:

- Static and dynamic stresses shall be safely absorbed,
- Underground water levels, the buoyancy force will not affect structural stability,
- During tunnel construction, the ground structure, water flow, ground parameters and chemical effects shall be investigated,
- Harmful gases will not exceed permissible levels. The Contractor shall carry out a formal gas hazard assessment covering the geological formations along the tunnel alignment to identify zones of potential gas occurrence. The assessment shall establish

monitoring protocols during construction, define threshold concentrations and response procedures, and specify ventilation design requirements. Results shall be incorporated into the Contractor's health, safety, and design submissions,

- Operations will not be affected by moisture,
- The volume of groundwater seepage will not exceed 5 millilitres per square metre per hour (5 ml/m²/h). The Contractor shall carry out a quantitative assessment of anticipated groundwater inflows into the tunnel, estimated by chainage and geological formation under minimum, maximum, and design groundwater level conditions. The results shall inform the design of water management measures including drainage, grouting, and waterproofing, and shall be submitted to the Engineer prior to finalising the lining and drainage design,
- In the event of a fire, the structural integrity will not be compromised,
- If air circulation is insufficient in the tunnel, at tunnel entrances, emergency exits and stations, additional measures will be taken,
- A comprehensive drainage system shall be installed to protect against water seepage and snow and rainwater carried by vehicles.

In areas where tunnels approach stations, measures will be taken to eliminate the vehicle's piston effect or minimise the air velocities caused by this effect. Air velocities caused by the vehicle's piston effect shall be within the following limits:

- Platforms (horizontal): 3,0 m/s average – 5,0 m/s maximum
- Stairs and escalators : 1,8 m/s average – 2,5 m/s maximum

Walkways and emergency lighting will be provided for passenger evacuation. Where necessary, a protective enclosure will be installed in the centre or at the side, depending on the track layout.

In tunnels where the direct-fixing track method is used, sound-absorbing materials will be used on the tunnel walls.

5.12.1.2. Bored Tunnels (NATM Tunnels)

The New Austrian Tunneling Method (NATM) is generally used in tunnel construction. NATM incorporates specific principles that enable tunnels to be excavated safely and economically. With the use of this method, stresses within the rock mass vary during the tunneling process. These stresses increase around the tunnel, causing deformations within the tunnel.

When a rigid support is used to control deformations in the rock mass, the support structure must bear excessive loads. However, if the formation of a stress belt in the rock is permitted and this belt is supported using ductile support methods—such as shotcrete reinforced with steel mesh and rock bolts—the load is reduced.

Consequently, using a less rigid support method will suffice to ensure the stability of the rock mass. This support typically includes elements such as shotcrete reinforced with steel mesh and rock bolts.

In NATM (New Austrian Tunneling Method) applications, the timing of the support is of critical importance. If the support is installed immediately after the tunnel excavation is completed, it may prove inadequate as it must bear a very heavy load at this stage. However, if the installation of the support is significantly delayed, there is a risk of tunnel collapse due to excessive deformation. Therefore, to ensure that the support is installed in a timely and correct manner, displacement and stress measurements must be carried out regularly during tunnel excavation, and these data must be evaluated by an experienced team. Furthermore, these measurements are used to make appropriate choices regarding the strength of the support elements during their design.

The basic support system elements used in tunnels are as follows:

- Sprayed Concrete: Concrete sprayed onto the tunnel's inner surface stabilises the rock mass.
- Steel Mesh and Reinforcement: These steel structures support and reinforce the tunnel walls.
- Truss Beams or Steel Profiles: These structures are used to support and reinforce the tunnel ceiling and side walls.
- Rock Bolts: These are steel rods used to anchor the rock mass to the tunnel.
- Drainage Pipes: Pipes used to keep water within the tunnel under control.

  Grouts: Materials injected into the ground to ensure soil consolidation and minimise settlement.

5.12.1.3. Tunnel Excavation Support Systems

The tunnel excavation and support system will be established in accordance with the rock classification system based on the internationally recognised Austrian standard ÖNORM B2203. This classification system is determined according to the rock support classes (Q) and (RMR)

values provided in Figure 5.24. The rock classes and their characteristics defined in ÖNORM B2203 are summarised below in Figure 5.12:

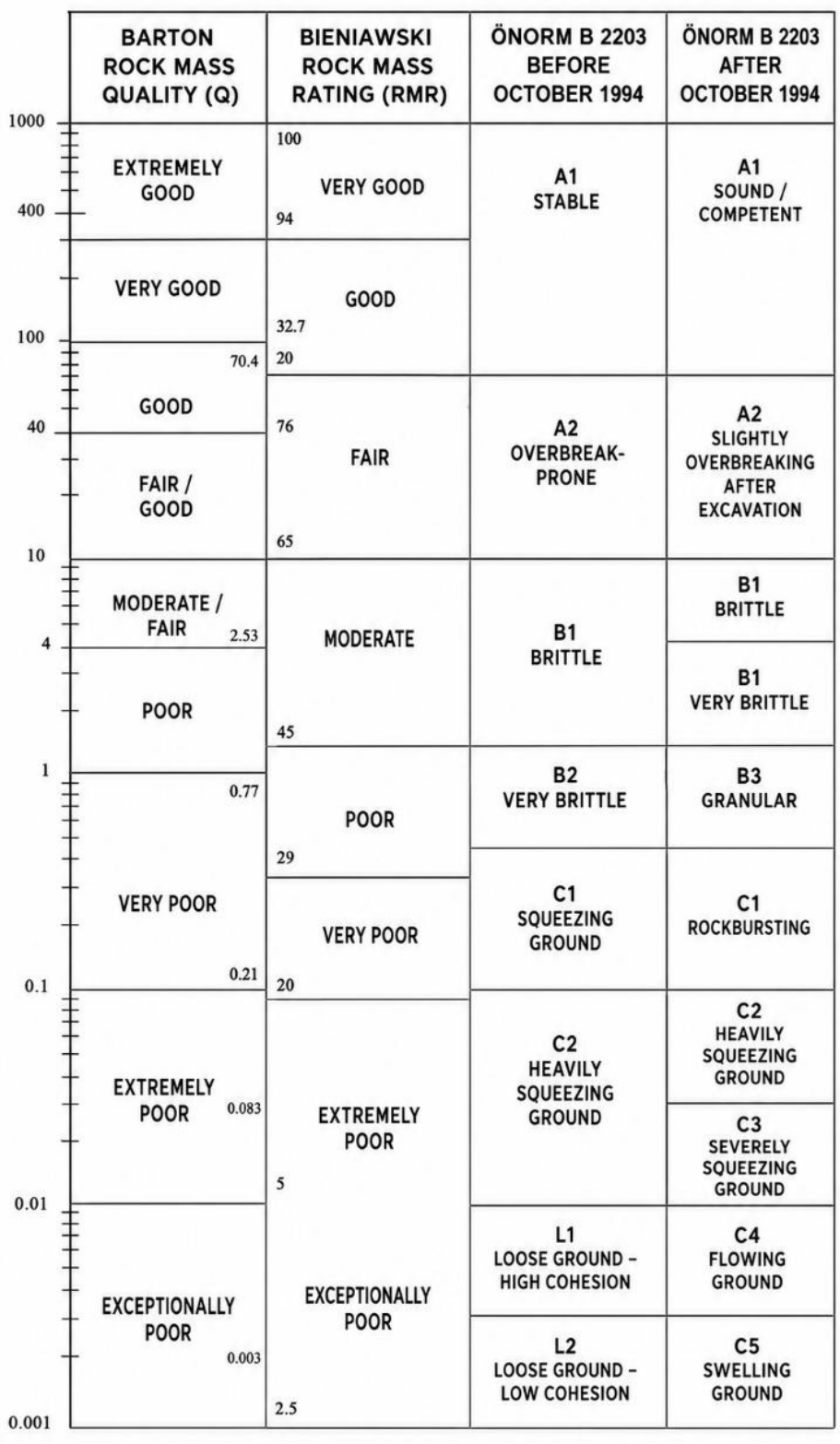


Figure 5.10 : Comparison of rock classification systems

“A” Rock Class: Rock class “A” is defined as “Stable-Slightly Overhanging Rock Masses”. This type of rock mass is generally stable and exhibits elastic behaviour. If local support is not applied, shallow collapses may occur in places due to gravity. Collapses generally occur due to isolated, insignificant joint structures. Elastic deformations diminish rapidly. Rock Class A is subdivided into two types: A1 (Stable) and A2 (Subsequently Slightly Weathered).

A1 Rock Mass Class: This is referred to as a “Stable” rock mass. The rock mass exhibits elastic behaviour. Deformations are small and diminish very rapidly. There is no tendency for rock fragments to detach once loose rock has been cleared. Water has no adverse effect on rock stability.

Tunnel excavation can theoretically be carried out as a “full face”. If the excavation profile is large, excavation is generally carried out in the form of upper and lower half excavation. Drilling and blasting will be required for the excavation. The advance length is selected depending on the soft blasting conditions and construction technique.

The support system will be shown in detail in the project documents.

Rock Mass Class A2: This is referred to as a “rock mass with minimal post-excavation settlement”. Deformations are small and diminish very rapidly. The rock mass exhibits elastic behaviour. There is a tendency for discontinuities and shallow spalling to occur in the tunnel roof and upper parts of the side walls due to the rock mass’s own weight. The effect of water on rock stability can be disregarded.

The tunnel excavation can theoretically be carried out as a “full-face” excavation. If the excavation profile is large, the excavation is generally carried out in two stages: upper and lower sections. Drilling and blasting will be required for the excavation. The advance length is selected based on soft blasting conditions and construction techniques. It is limited to 2,5–3,5 m in the upper section and 4 m in the lower section.

In this support class, rock bolts may only be used locally to stabilise in-situ blocks in the tunnel roof or side walls. In this case, the rock bolts to be used shall be installed no more than one advance step behind the face. The direction of rock bolting shall be selected according to the orientation of the discontinuities. Bolting and other supports shall be shown in detail in the project documents.

“B” Rock Class: Rock Class “B” is defined as “Fragile Rock Masses”. The behaviour of rock masses designated as “B” is prone to rapid loosening and disintegration due to a lack of structural interlocking and/or tensile strength. In almost the entire surrounding area, secondary stresses near the void slightly exceed the rock mass’s strength; however, this failure mechanism does not extend into the interior. Delays in support construction result in increased subsidence. Rock class B is subdivided into three types: B1 (Brittle), B2 (Very Brittle) and B3 (Grainy).

B1 Rock Mass Class: This is referred to as a 'brittle' rock mass. Deformations are small and diminish very rapidly. Loosening of the rock caused by blasting and the low strength of the rock mass lead to spalling on the tunnel roof and the upper parts of the side walls. The effect of water on rock stability can generally be considered negligible.

Tunnel excavation is carried out in two stages: the upper and lower sections. The advance length will be between 2,0–3,0 m in the upper section and 4,0 m in the lower section. The advance length must be adjusted according to the unsupported standing time of the ground, the unsupported span, and the time required to install support elements. Drilling and blasting are required for the excavation.

Systematic support is required in restricted areas. Localised advance support may be necessary. Support shall be installed no more than one advance step behind the face. Hazardous areas shall be supported immediately. The support system shall be shown in detail in the project documents.

B2 Rock Mass Class: This is referred to as a 'very friable' rock mass. Deformations decrease rapidly if tunnel support is installed in a timely manner. If support is not installed in a timely manner or if the support elements are inadequate, loosening extending to greater depths and associated failures will occur. Excessive water flow into weathered or fragmented rock mass has an effect on the strength of the rock mass.

Excavation is divided according to the tunnel cross-section. The advance length is determined based on the unsupported standing time and the unsupported span. The advance length will not exceed 1,5–2,0 m in the upper half and 3,0–3,5 m in the lower half. Excavation is generally carried out using soft blasting. Systematic support is required for the tunnel roof and side walls.

Where necessary, a roof beam will be used. The adverse effects of drilling and similar operations on the rock mass in the face or on the roof will be prevented. The support system will be shown in detail in the project documents.

Rock Mass Class B3: This is referred to as a "granular" rock mass. Even in split excavation, rock mass failure occurs. Low cohesion and low cementation lead to instability in the excavation. Excessive water flow into weathered or fragmented rock mass affects the strength of the rock mass.

In order to proceed with split-level excavation, measures must be taken to stabilise the rock mass and increase the unsupported standing time. The advance length shall not exceed 1,25–1,50 m in the upper section and 3 m in the lower section. Excavation is generally carried out using soft blasting; mechanical excavation methods will be used in rock masses sensitive to vibration. A base excavation and the construction of a base concrete arch may be necessary.

Systematic support must be installed in the tunnel roof and side walls, at the face and prior to the advancement of the face. The use of struts may be required locally. Systematic steel shoring will be used. Depending on geological conditions, it may be necessary to construct a cast-in-situ base arch concrete, situated no more than 75–100 metres behind the upper face. The support system will be shown in detail in the project documents.

"C" Rock Class: Rock class "C" is defined as "Compressed Rock Masses". The behaviour of rock masses designated as "C" generally indicates that the stresses resulting from the process of rock pressure redistribution and/or displacement constraints exceed the rock's strength. When the rock mass is subjected to excessive stresses, failure mechanisms such as spalling, buckling, shearing and plastic movement towards voids occur. The plasticity and viscosity of the rock mass cause it to exhibit time-dependent deformation behaviour, ultimately leading to large deformations. The activation of rock self-weight loads and the generation of significant relaxation pressure occur only when large deformations are permitted. This situation, involving relaxation and disintegration to a degree that damages the rock mass, leads to a substantial reduction in rock strength. Large deformations within the void and time-dependent displacement behaviour over the long term depend on the soil's inelastic, plastic and viscous behaviour. Rock masses prone to cracking or disintegration, and those containing components with swelling properties, fall into this group. This group also encompasses rock masses such as weathered or degraded rocks, loose soils and organic soils. Due to the low properties of the rock mass, elastic or plastic deformations occur as a result of the amount of cohesion and/or excessive stresses following loosening pressure. Rock Class C is subdivided into five types: C1 (Rockfall), C2 (Pressed), C3 (Highly Pressed), C4 (Flowable) and C5 (Swelling).

C1 Rock Mass Class: High pre-stresses in massive rock beneath a thick overburden lead to the storage of elastic energy in the brittle rock mass. The sudden release of this energy causes fractures in the rock, accompanied by shearing and crushing of the rock structure. In unsupported sections, flying rock fragments are prone to fragmentation. Fractures in the rock mass extend to great depths. The inflow of excessive water into weathered or disintegrated rock mass has a significant effect on the rock mass's strength.

Excavation should proceed in sections. A bottom excavation is required. The advance length shall not exceed 1.5–2.0 m in the upper half and 3 m in the lower half. Excavation may be carried out using controlled blasting or mechanical excavation methods.

Short but densely spaced rock bolts and steel mesh are required as support elements. As an additional measure, pressure-reducing holes may be drilled into the rock mass. This method can also prevent rock bursts. Depending on geological conditions, it may be necessary to construct a cast-in-situ base arch concrete structure no more than 50–75 m behind the upper bench face. The support system will be shown in detail in the project documents.

C2 Rock Mass Class: This is referred to as a ‘compressed’ rock mass. C2 is characterised by plastic zones extending deep into the surrounding rock mass and a pressure-generating behaviour. In this rock mass, moderate but distinctly prolonged deformations that subside slowly are observed. The magnitude and rates of deformation around the excavation are moderate. Stress is observed in high-cohesion rock masses exhibiting plastic behaviour. Water seepage and concentrated water flow have a significant effect on the rock mass.

The tunnel excavation must be divided into the upper, lower and base excavations. With the exception of special cases in the portal areas, the upper excavation will be subdivided into sections. A support structure will be required on the upper bench face. The advance length will not exceed 0.75–1.25 m on the upper bench and 2 m on the lower bench. Excavation may be carried out using controlled blasting and mechanical excavation methods. A shotcrete lining is required immediately after cutting.

The tunnel face is generally stable. Systematic support is required around the entire cross-section. Progress to the next advance step will only be made once the support system has been completed for each advance step. A continuous lining application will be required on the tunnel roof. To prevent adverse effects on the rock mass in the tunnel face and roof during the drilling sequence and subsequent construction, measures must be taken. The role of the support elements is to limit deep plastic fractures. A base arch is required, situated no more than 50 m behind the upper half of the tunnel face, in accordance with geological conditions. The support system will be shown in detail in the project documents.

In segmented excavations to be carried out in wide cross-sections, it is important to form the section to be left as a central pillar in a buttress shape to assist with arching. To assist, even partially, in the formation of a stress arch, the excavation cross-section should not be gradually widened in the same direction by lateral scanning.

C3 Rock Mass Class: ““Highly stressed” rock mass. C3 is characterised by the formation of deep zones of weakness, initially accompanied by high and rapid deformations. These deformations persist for a long time and subside slowly. Fractures and plastic zones extending into the depth are observed. Water seepage and concentrated water flow have a significant effect on the behaviour of the rock mass.

The tunnel excavation must be divided into the upper half, the lower half and the base excavation. A support structure will generally be required in the upper half excavation face. Systematic support may be required in the face. The advance length shall not exceed 1.2 metres in the upper half excavation and 2.0 metres in the lower half. Excavation will generally be carried out using soft blasting or mechanical excavation methods. A shotcrete lining is required immediately after cutting. A dense support pattern will be required across all excavation faces. Special arrangements will be required, such as the use of support elements capable of withstanding deformation levels, deformation voids and/or large deformations. The support elements shall

maintain the triaxial stress state of the rock mass. Should shortening the advance step length, extending the bench length, and leaving a large central support body in the upper bench prove insufficient, the bench excavation may need to be further subdivided into lower sections. Possible solutions may include carrying out the upper half excavation in the form of half-excavations or side galleries. Should the complete excavation section exhibit excessive vertical movements, it may be necessary to widen the lining foundation, bolt and grout the base region of the shotcrete shell, or install temporary base arches.

In segmented excavations to be carried out in wide sections, it is important to form the section to be left as a central pillar in a buttress shape to assist with arching. To assist, even partially, in the formation of a tension arch , the excavation section should not be progressively widened in the same direction from the side.

Furthermore, it is beneficial to leave a central core in the middle of the excavation face.

All tunnel support is installed systematically before further advancement of the upper and lower excavation faces. The use of a continuous pipe will be required across the entire roof section. The adverse effects of drilling or similar operations on the rock mass at the face or roof will be prevented. In the upper half excavation, cross-sections divided into lower sections and temporary ring structures may be required. Ring closure of the base arch may be required 25–50 metres behind the upper half excavation face. The support system will be shown in detail in the project documents.

Rock Mass Class C4: This is referred to as a ‘flowing’ rock mass. Very low cohesion and friction, combined with the rock mass’s low plastic behaviour, cause material to flow into the tunnel even in a split excavation left unsupported for a short time. Low cohesion necessitates numerous sub-divisions in the excavation. The ground has no self-supporting period unless pre-tunnelling installation is carried out or sprayed concrete lining is applied simultaneously with the excavation. Water seepage and concentrated water flows may have a significant effect on the behaviour and properties of the exposed ground. Therefore, measures to improve the strength of the rock mass may be considered. To prevent stability issues in the tunnel face, a subdivision in the form of side galleries will be required. Additionally, support structures are required for the upper and lower tunnel faces. It is possible to allow for limited excavation thanks to the supporting effect of the tunnel face, achieved through advance support or special support measures. The advance length will not exceed 1.5 m in the upper bench and 2.0 m in the lower bench. Excavation will be carried out using a tunnel excavator. Shotcrete lining is required in conjunction with the excavation.

Tunnel support must be completed in each advance step in both the upper and lower sections. Support pipes or steel plate supports will, of course, be required for the majority of the roof section. A support system comprising shotcrete, steel mesh, rock bolts and drainage elements may need to be used on the excavation face during or immediately after excavation. Sprayed concrete lining must be carried out in conjunction with the excavation of the section divided into subsections. The

installation of a lining is mandatory. Temporary ring closure may be required in the subsections of the upper half excavation. Ring closure in the base arch may be necessary over short distances of between 25 and 50 metres behind the upper half excavation face. The support system will be shown in detail in the project documents.

Rock Mass Class C5: This is referred to as a “highly cohesive, short-term stable” rock mass. In rock masses containing swelling-prone clay minerals, salt or anhydrite, loosening occurs due to volume expansion caused by water absorption. By limiting free openings in the arch and face, the rock mass can remain stable for a limited period. Seepage and concentrated water flow have a significant effect on the behaviour and properties of the excavated ground. Swelling may have already commenced.

It is essential to divide the excavation into upper, lower and base sections. In many cases, a support structure will be required for the upper section face. Advance lengths shall not exceed 1.5 metres in the upper section and 3.0 metres in the lower section. Excavation may be carried out using a tunnel excavator. Blasting may be required when excavating large boulders or locally hard rock sections.

Tunnel support must be completed in both the upper and lower halves at each advance step. The installation of continuous pipe or steel sheet piling will be required for the majority of the roof section. Sprayed concrete lining must be applied in conjunction with the excavation of the section divided into subsections. A base arch is required, situated no more than 25 metres behind the upper face, in accordance with geotechnical requirements. The excavation cross-section may need to be approximated as closely as possible to a circular cross-section. The support system will be shown in detail in the project documents.

Based on the data obtained from on-site and laboratory tests conducted on the boreholes and core samples taken along the tunnel alignment, the tunnel is classified into the various rock classes defined above in accordance with ÖNORM B 2203. For each rock class, the design of the excavation system will include primary support elements (shotcrete, steel mesh, steel shoring, struts, bolts, etc.) and secondary support elements (lining concrete).

Excavation Support System Analyses

The NATM bored tunnel excavation support system analysis will begin by identifying critical sections, taking into account factors such as tunnel geology, overburden thickness, groundwater level and structures above the tunnel, in order to determine the types of support required. In these critical sections, fundamental geotechnical parameters will be determined using rock mechanics principles for the analysis of idealised rock units.

The analyses will be carried out using finite element analysis software. Whilst soil and rock elements will be defined using the software’s triangular elements, support and lining elements

(shotcrete and reinforced concrete lining) will be defined using custom elements. The analyses will be carried out using a conservative approach, and only the shotcrete will be modelled within the support elements. As drainage is provided within the tunnel during the support phase, groundwater pressure will not be taken into account in the analysis of the support elements.

All excavation stages will be modelled, and prior to activating the support elements in each stage, a suitable relaxation coefficient will be applied to model three-dimensional relaxation effects. Once all excavation stages have been modelled, the displacements and section effects (moment, axial force, shear force) occurring in the support elements will be reported as a result of the analysis.

To analyse long-term conditions, the support elements will be deactivated, and the internal lining elements will be activated. To represent long-term critical conditions, the groundwater level identified in the geological profile will be defined, and the internal lining elements will be subjected to this water pressure.

Analyses will be carried out taking into account detailed excavation geometry and surcharge loads appropriate to the number of storeys of surrounding buildings. All excavation and construction stages will be modelled, and the displacements and section forces (moment, shear force, axial force) occurring in the rock and support system elements at each stage will be reported. The analysis results will include the expected vertical displacement and angular rotation values in the surrounding structures, and it will be demonstrated that the selected excavation support system meets the limits specified in national and international regulations.

During tunnel construction, the stages of classifying the rock and soil encountered during excavation and support, and preparing excavation/support design schemes, will be sequenced as follows:

1. Geological-geotechnical report: Prior to the commencement of tunnel construction, a report containing fundamental information such as the strength and physical properties of the soil and rock, the groundwater level, and the tunnel's surroundings will be prepared. Separate calculation models will be developed for different rock classes.

2. Design of tunnel support systems and excavation stages: At this stage, tunnel support systems and excavation stages are determined using numerical (Finite Element, Finite Difference, Boundary Element) and analytical calculations (Hoek and Brown). In these calculations, it must be possible to model unsupported and supported excavation stages, depending on the rock class during tunnel construction, as well as the tunnel geometry and different material compositions (bolts, shotcrete, etc.). The following conditions must be taken into account in the calculations.

    - Initial stress conditions: The condition in which the environment in which the tunnel excavation is to be carried out is subjected to stresses arising from its own weight.

- Final excavation condition: The unsupported state following excavation, or the state at the previous stage in the case of phased excavation.

- Final state of primary support: The final state of the tunnel after all support works have been completed.

- Interaction between excavation support stages and tunnel tubes: Interactions between twin tunnels and those caused by the tunnel being excavated first are taken into account in the calculations.

- Final construction condition: The final condition in which the lining concrete has been cast, and the effect of groundwater has been taken into account.

- Lining concrete: Consists of impermeable concrete containing reinforcement amounting to at least 0.15% of the cross-sectional area.

3. Standard support and excavation designs: Standard support designs and designs showing the standard sequence of excavation and support works will be prepared in accordance with the excavation and support system.

4. Tunnel tubes: Suitable sections are selected based on calculations for sections with pedestrian and vehicular traffic. Standard support and excavation designs will be provided for these sections.

5. Water-bearing soil/rock layers: Special excavation and support designs will be prepared for water-bearing soils.

6. Excavation method and equipment: The appropriate excavation method and equipment will be determined for each rock class. For rock classes where blasting excavation is recommended, a blasting pattern will be designed during construction (in accordance with the blasting excavation specifications).

7. Geotechnical monitoring programme: A geotechnical monitoring programme and typical monitoring sections will be prepared to monitor deformation, settlement and stress increases during construction. These measurements will be presented in tabular form, including the anticipated deformation values for each rock class.

8. Changes and verifications: Situations arising during construction will be examined and compared with the conditions specified in the project. Where necessary, changes will be made to the excavation support system.

▪ **Design Methods**

In general, the support design will ensure tunnel stability and will consist of a specific type of support to be applied to the tunnel, either in the form of a permanent lining or a support system. The support in question will be verified using the characteristic curve method (Deformation Limitation Method) in accordance with the general principles of preliminary support design.

Temporary and permanent linings will be designed and verified using internationally recognised software employing the Finite Element/Differences Method.

In areas where intersections between underground excavations and interactions between adjacent excavations are possible, 3D modelling will be carried out for verification.

The permanent lining design will be carried out on the assumption that it bears all loads applied by the ground as well as all hydrostatic loads acting on the tunnel.

▪ **Characteristic Curve Method**

The most commonly used approach for determining the horizontal and vertical loads applied by the rock mass on the lining is the Deformation Constraint Method or the Characteristic Curve Method. These frequently used methods model soil–structure interaction as an axially symmetric problem involving a radial pressure applied around a circular opening situated in an elasto-plastic medium subjected to hydrostatic stress. This problem can be solved analytically by evaluating the support and soil characteristic curve (SCC) or the ground reaction curve (GRC).

The ground reaction curve relates the convergence of the excavation profile to the soil pressure acting on the support. For any combination of tunnel radius and ground stress state, the GRC is a function of the rock mass stiffness and strength parameters, which can be expressed using the accepted failure criterion, Young’s Modulus and the uniaxial compressive strength of the rock mass.

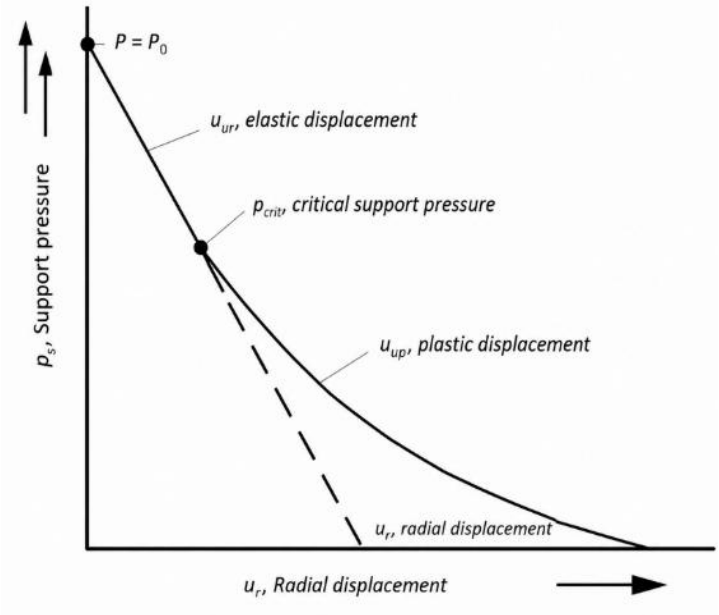


Figure 5.11 : Soil reaction curve illustrating the relationship between the tunnel lining and the excavation support (Hoek 1995)

On the other hand, the support can be modelled as a linear elastic-fully plastic material. The support characteristic curve is a function of the support's stiffness, the maximum permissible pressure of the support, and the support's current convergence. When the support is installed and becomes active, it begins to deform elastically until it cuts through the GRC. The equilibrium point between the two curves represents the final settlement that will occur and also the pressure acting on the support. The support is capable of withstanding the applied pressure only if the equilibrium point is at the yield pressure of the support system with a sufficient safety factor.

▪ Definition of the Calculation Method

The following steps will be used for the tunnel support to be designed according to the Characteristic Curve Method: The excavation method, overburden thickness and geology are taken into account to select the design cross-sections. A preliminary definition of support requirements is made according to the RMR Class. Soil reaction curves are calculated.

Characteristic curves are calculated for the proposed cross-section using appropriate safety factors. The details of the calculation steps are shown below.

▪ Determination of Design Cross-Sections

For each excavation section where support is to be designed, the calculation steps will be selected in accordance with FHWA or ITA principles, taking into account the worst-case combination of conditions—including ground parameters, water, and tunnel lining geometry—until the section length encompasses different characteristics.

▪ **Estimation of Preliminary Support Based on RMR Classification**

The initial design of the support will be based on the RMR Classification of the ground as shown in the geotechnical reports. This support will be used to verify the design sections defined in the following sections.

In addition to the selection of sections where geology may vary and yield critical results, the following critical conditions may need to be evaluated through numerical calculations:

- Case: The case where the overburden thickness is at its maximum.
- Case: The condition where the cover thickness is at its minimum.
- Scenario: The scenario where the groundwater level is at its highest.
- Condition: The condition where the groundwater level is at its lowest.
- Condition: Sections where significant surcharge loads are present.
- Condition: Sections subjected to eccentric loading.
- Condition: Sections where the ground surface is uneven.
- Condition: Sections where adjacent tunnels currently exist or where the construction of adjacent tunnels is planned in the near future.

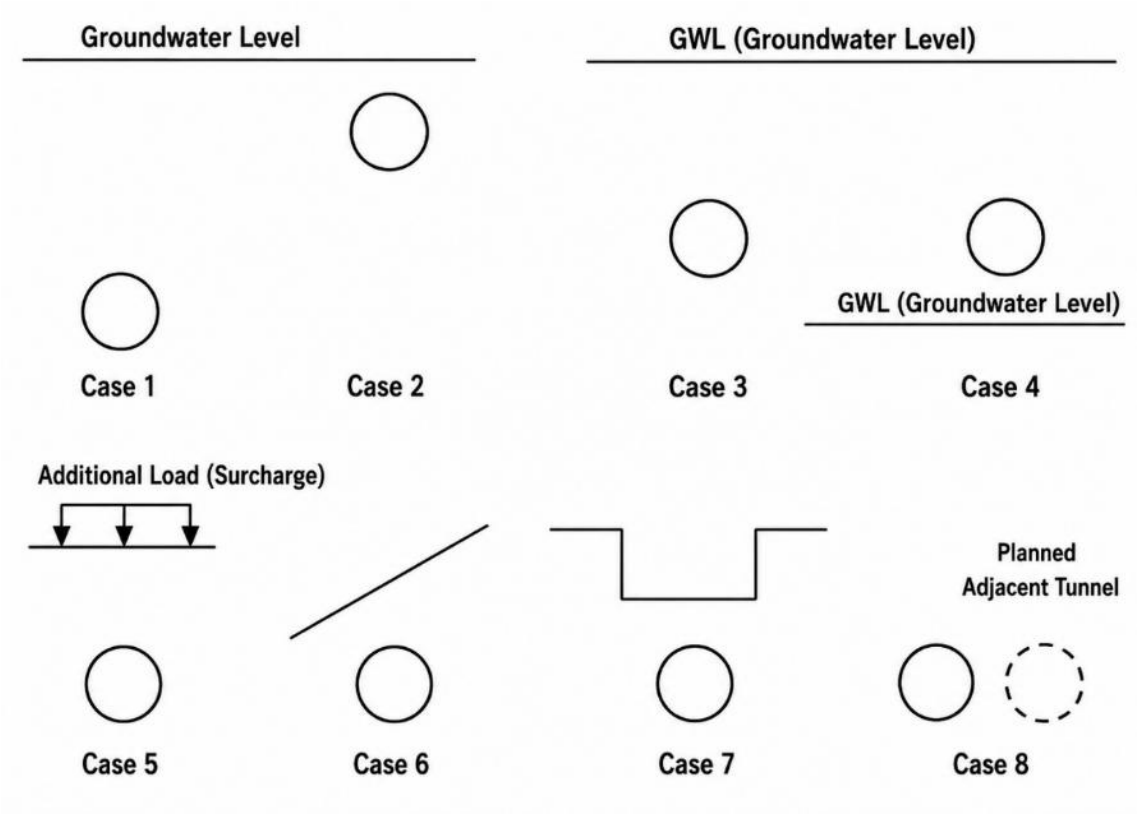


Figure 5.12 : ITA principles applied to the proposed design cross-sections

In order to minimise surface deformation and radial deformation caused by underground excavation, high loads and safety factors will be adopted for relatively shallow tunnels in sections where settlement is concentrated around the tunnel. Particularly in regions with high tectonic activity, geological conditions can change rapidly and lead to adverse conditions emerging in nearby areas. Therefore, in such situations, additional support and special measures will be preferred.

▪ Ground Reaction Curves

Ground Reaction Curves (GRCs) will be calculated for each tunnel section using appropriate software for a circular-section tunnel with the same cross-sectional area as the excavation section. The selected failure criterion will be the Mohr–Coulomb or Hoek–Brown failure criterion. Secondary ground stresses will be calculated for each tunnel cross-section based on available geological and topographical data. The steady-state earth pressure coefficient and geological load will be taken into account.

The required data set comprises the following parameters:

K0 is defined as v/(1-v) in rock and (1-sinϕ) in soil.

Overburden thickness (m)

Equivalent tunnel radius, defined as r = √(A/¶)

σci, global compressive strength of the rock mass [kPa]

σrm, global compressive strength of the rock mass [kPa]

Ei, elastic modulus of sound rock [kPa]

Erm, Modulus of elasticity of the rock mass [kPa]

v: Poisson’s ratio

c, Cohesion [kPa]

Ø, Internal friction angle [°]

ɣ, Unit weight [kN/m³]

Rock mass parameters will be determined using the following procedure. The uniaxial compressive strength of the rock mass will be determined from the properties of sound rock (σc, Young’s modulus, Hoek-Brown constants ‘mi, s and a’) and the Geological Strength Index (GSI) using the relevant chart. The parameters of the failure criterion envelope will be converted back to equivalent failure parameters in terms of the Mohr–Coulomb failure criterion (angle of friction and cohesion).

▪ Calculation of Support Characteristic Curves

Internal support shall consist of shotcrete, rock bolts, steel mesh or truss beams, or a combination thereof. The maximum support deformation at the point of yielding shall be calculated for each support element, and subsequently, the Support Characteristic Curves (SSC) of the support system shall be defined by the combined deformation of the various elements at the point of yielding and the combined maximum support pressure. The effects of steel mesh and radial bolts will be disregarded. For truss beams and shotcrete, the maximum pressure can be calculated using the formulations of theories developed for hollow cylinders under external pressure. The deformations at the moment of yielding for each support type will be calculated based on the available technical literature.

The calculation of the maximum support pressure for sprayed concrete can be carried out in accordance with relevant standards, taking full account of load amplification requirements.

▪ Structural Verification of the Support

Soil-support interaction will be analysed using appropriate software.

▪ Design Using Numerical Methods

The support will be structurally verified using the Deformation Constraint Method. Both the interaction between adjacent excavations and the permanent lining will be modelled using precise numerical methods. The selected numerical method will be internationally recognised software based on the finite element/difference method.

▪ Design Sections

Loads on the lining will be selected to include water, geological loads, ground parameters and adjacent structures, taking into account the worst-case combination, and will be calculated for the relevant tunnel cross-sections. In the tunnel cross-sections, the same design cross-sections, defined in accordance with FHWA or ITA Principles, will be used for support verification.

▪ Loads

In the numerical model used for calculating lining loads, the presence of water and the geometry of the variable overburden layer will also be taken into account. The permanent lining will be designed on the assumption that it must carry all ground loads; the presence of the excavation support system will not be considered in permanent lining analyses. The interaction between the support system and the excavation, and the presence of the support system, will be taken into account solely to determine the deformation ratio estimated using the Characteristic Curve Method, which is included in the model.

For traffic loads, a load of at least 20 kN/m² on the ground surface will be considered; however, a detailed investigation will be carried out in areas with heavy vehicle loads. For each storey of residential buildings, a surcharge load of 15 kN/m² and 20 kN/m² for the foundations will be taken into account.

▪ Software to be Used

Numerical calculations are performed using internationally recognised software that employs two-dimensional and three-dimensional finite element/difference methods developed to solve tunnel excavation problems and geotechnical problems under plane strain conditions.

▪ Modelling

The volume of the relevant geotechnical soil is modelled as a network of triangular elements containing different geotechnical layers based on constitutive models such as linear elastic, Mohr-Coulomb, elasto-plastic hardening soil, hardening soil small strain, and Hoek-Brown, with the behaviour determined by the soil type. The Hardening Soil Constitutive Law adds greater flexibility to the elements than the loading stiffness, creating a model that accounts for rock behaviour and the tunnel's influence during excavation. At the same time, the permanent lining will be modelled simply as plane elements. The calculations for the Continuous Medium Model will be carried out step by step.

▪ Standards for Structural Calculations

For the loads to be used in lining analyses, European Standard Eurocode 2 may be used alongside TS 500. In accordance with Eurocode 2, the service limit state (SLS) and ultimate limit state (ULS) will be considered for the structural analyses of the permanent lining.

▪ Permanent Lining Analyses

Seismic calculations may be performed in accordance with the FHWA Technical Manual for Design and Construction of Road Tunnels – Civil Elements or the "Deformation Method", as specified by the International Tunneling Association (ITA) and the Association Française des Tunnels et de l'Espace Souterrain (AFTES).

Maximum Stress Control: To prevent the formation of micro-cracks or longitudinal cracks, the maximum stress must remain below the permissible stress values for steel and concrete. Crack Width: The limit values specified in TS500 for crack width shall be taken into account.

▪ Material Properties

The support system shall consist of rock bolts, PG-SN bolts, truss beams, steel formwork and/or shotcrete. The permanent lining shall consist of in-situ cast concrete.

The internal lining design will be carried out using in-situ concrete, utilising concrete of at least C35 class and B420C reinforced steel in accordance with Turkish Standard TS 500.

- **Floatation Analysis**

Loads causing buoyancy and the overall safety of the structure against buoyancy will be assessed throughout the project's lifespan, taking into account the water levels specified in the loads section and the requirements of European Standard Eurocode 7.

Floating-induced loads shall be treated as additional permanent loads.

- **Reference Documents**

- "Guidelines for the Design of Shield Tunnel Lining" – ITA - Tunnel and Underground Space Technology, Vol. 15, No. 3 – 2000
- "Guidelines for the Design of Tunnels" – ITA - Tunnel and Underground Space Technology, Vol. 3, No. 3 – 1988 "Engineering rock mass classifications" – Bieniawski, Z. T. – New York
- "Guidelines for Earthquake Design and Protection of Underground Structures" – AFTES – 2001. "Recommendations on the Convergence-Confinement method" – AFTES – 2001
- Working Group No. 7 – Temporary Supports and Permanent Lining. "Considerations on the usual methods of tunnel lining design" – AFTES – 1988
- "Analysis of convergence behind the face of a tunnel" – Panet M, Guenot A. – Tunneling 82 Brighton, pp 197,204 – 1982
- European Specification for Sprayed Concrete – Efnarc – 1996

5.12.1.4. Preparation of Standard Design Projects for Tunnel Excavation Support

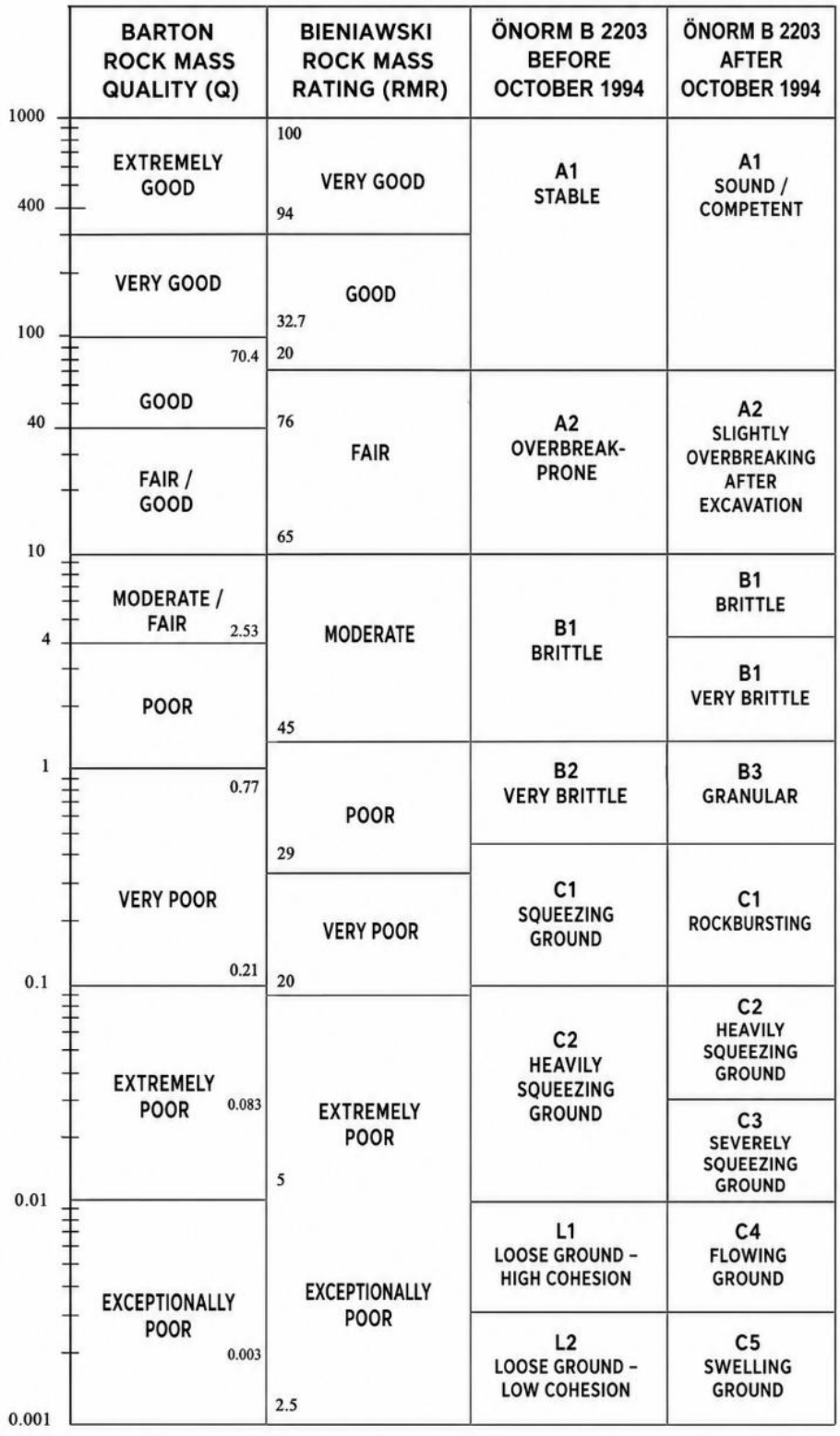
In general, bored tunnels are constructed using the New Austrian Tunnelling Method (NATM). NATM incorporates a number of principles that enable tunnels to be excavated both safely and economically. During tunnelling, stresses in the rock mass, which were previously in equilibrium, shift to a new equilibrium state; these stresses increase in a direction parallel to the tunnel face and deformations occur towards the tunnel interior. If these rock deformations are prevented by a rigid support, the load on the support will be excessive; however, if the support is designed to be ductile, allowing for some deformation, the load will be reduced. In this case, a ductile and slender support system comprising shotcrete reinforced with steel mesh and rock bolts is sufficient to ensure the stability of the rock mass. In NATM, great importance is attached to the timing of the support. If a rigid support is installed immediately after excavation, it may prove inadequate due to the high load placed upon it. Conversely, if the initial support is installed too late, collapses may occur due to excessive loosening. To ensure that the support is installed at exactly the right time, regular displacement and stress measurements must be carried out in

parallel with the tunnel excavation, and these must be evaluated by an experienced team. These measurements are also necessary to decide whether the support should be selected to be weaker or stronger than that envisaged in the design. The main elements of the support systems used in tunnels are listed below:

- Sprayed concrete
- Steel mesh
- Truss beams or steel sections
- Rock bolts
- Anchor pipes

The tunnel excavation and support system will be designed in accordance with the rock classification system established under the internationally recognised Austrian standard ÖNORM B2203. This classification system is determined based on the rock support classes (Q) and (RMR) values given in Figure 5.12.

Table 5.4 : Comparison of Rock Classification Systems



The rock classes and their characteristics as defined in ÖNORM B2203 are summarised below:

“A” Rock Class: Rock class A is defined as “Stable-Slightly Overhanging Rock Masses”. Rock masses of this type are generally stable and exhibit elastic behaviour. In the absence of local support, rock fragments and blocks may fall from the roof and side walls due to gravity. Block falls generally occur due to isolated, insignificant joint structures. Elastic deformations decrease rapidly. Rock Class A is further divided into two types: A1 (Stable) and A2 (Subsequently Slightly Weathered).

A1 Support Class: This is referred to as a ‘Stable’ rock mass. The rock mass exhibits elastic behaviour. Deformations are small and diminish very rapidly. There is no tendency for rock fragments to detach once loose rock has been cleared. Water has no adverse effect on rock stability.

Tunnel excavation can theoretically be carried out as a “full face”. If the excavation profile is large, excavation is generally carried out in the form of upper and lower half-excavations. Drilling and blasting will be required for the excavation. The advance length is selected depending on the soft blasting conditions and construction technique.

The support system will be shown in detail in the project documents.

Support Class A2: This is referred to as a “rock mass with minimal post-excavation settlement”. Deformations are small and diminish very rapidly. The rock mass exhibits elastic behaviour. There is a tendency for discontinuities and shallow spalling to occur in the tunnel roof and upper parts of the side walls due to the rock mass’s own weight. The effect of water on rock stability can be disregarded.

The tunnel excavation can theoretically be carried out as a “full-face” excavation. If the excavation profile is large, the excavation is generally carried out in two stages: upper and lower halves. Drilling and blasting will be required for the excavation. The advance length is selected based on soft blasting conditions and construction techniques. It is limited to 2.5–3.5 m in the upper half and 4 m in the lower half.

In this support class, rock bolts may only be used locally to stabilise in-situ blocks in the tunnel roof or side walls. In this case, the rock bolts to be used shall be installed no more than one advance length behind the face. The direction of rock bolting shall be selected according to the orientation of the discontinuities. Bolting and other supports shall be shown in detail in the project documents.

“B” Rock Class: Rock Class “B” is defined as “Fragile Rock Masses”. The behaviour of rock masses designated as “B” is prone to rapid loosening and disintegration due to a lack of structural interlocking and/or tensile strength. In almost the entire surrounding area, secondary stresses near the void slightly exceed the rock mass’s strength; however, this failure mechanism does not

extend into the interior. Delays in support construction result in increased subsidence. Rock class B is subdivided into three types: B1 (Brittle), B2 (Very Brittle) and B3 (Grainy).

B1 Support Class: This is referred to as ‘Brittle’ rock mass. Deformations are small and diminish very rapidly. Loosening of the rock caused by blasting and the low strength of the rock mass lead to spalling on the tunnel roof and the upper parts of the side walls. The effect of water on rock stability can generally be considered negligible.

Tunnel excavation is carried out in two stages: the upper half and the lower half. The advance length will be between 2.0–3.0 m in the upper half excavation and 4.0 m in the lower half. The advance length must be adjusted according to the unsupported standing time of the ground, the unsupported span, and the time required to install the support elements. Drilling and blasting are required for the excavation.

Systematic support is required in restricted areas. Localised advance support may be necessary. The support system will be installed no more than one advance step behind the tunnel face. Hazardous areas will be supported immediately. The support system will be shown in detail in the project documents.

B2 Support Class: This is referred to as a ‘very friable’ rock mass. Deformations decrease rapidly if tunnel support is installed in a timely manner. If support is not installed in a timely manner or if the support elements are inadequate, loosening extending to greater depths and associated failures will occur. Excessive water flow into weathered or fragmented rock masses has an effect on the strength of the rock mass.

Excavation is divided according to the tunnel cross-section. The advance length is determined based on the unsupported standing time and the unsupported span. The advance length will not exceed 1.5–2.0 m in the upper half of the excavation and 3.0–3.5 m in the lower half. Excavation is generally carried out using soft blasting. Systematic support is required for the tunnel roof and side walls.

Where necessary, a roof beam will be used. Measures will be taken to prevent drilling and similar operations from adversely affecting the rock mass in the face or on the roof. The support system will be shown in detail in the project documents.

B3 Support Class: This is referred to as a ‘granular’ rock mass. Even in split-level excavation, rock fall occurs within the rock mass. Low cohesion and poor cementation lead to instability in the excavation. Excessive water flow into a weathered or disintegrated rock mass has an impact on the rock mass’s strength.

To proceed with split excavation, measures must be taken to improve the rock mass and increase the unsupported standing time. The advance step length shall not exceed 1.25–1.50 m in the

upper half of the excavation and 3 m in the lower half. Excavation is generally carried out using soft blasting; in rock masses sensitive to vibration, mechanical excavation methods will be used. A base excavation and the construction of a base concrete arch may be necessary.

Systematic support must be installed in the tunnel roof and side walls, in the face, and prior to the advancement of the face. The use of temporary support may be required locally. Systematic steel shoring will be used. Depending on geological conditions, it may be necessary to construct a cast-in-situ base arch concrete, situated no further than 75–100 metres behind the upper face. The support system will be shown in detail in the project documents.

“C” Rock Class: Rock class “C” is defined as “Compressed Rock Masses”. The behaviour of rock masses designated as “C” generally indicates that the stresses resulting from the process of rock pressure redistribution and/or displacement constraints exceed the rock’s strength. When the rock mass is subjected to excessive stresses, failure mechanisms such as spalling, buckling, shearing and plastic movement towards voids occur. The plasticity and viscosity of the rock mass cause it to exhibit time-dependent deformation behaviour, ultimately leading to large deformations. The activation of rock self-weight loads and the generation of significant relaxation pressure occur only when large deformations are permitted. This situation, involving relaxation and disintegration to a degree that damages the rock mass, leads to a substantial reduction in rock strength. Large deformations within the void and time-dependent displacement behaviour over the long term depend on the soil’s inelastic, plastic and viscous behaviour. Rock masses prone to cracking or disintegration, and those containing components with swelling properties, fall into this group. This group also encompasses rock masses such as weathered or degraded rocks, loose soils and organic soils. Due to the low properties of the rock mass, elastic or plastic over-stresses occur as a result of the amount of cohesion and/or excessive stresses following loosening pressure. Rock Class C is subdivided into five types: C1 (Rockfall), C2 (Pressed), C3 (Highly Pressed), C4 (Flowable) and C5 (Swelling).

C1 Support Class: Excessive natural stress and high overburden pressure cause elastic energy to be stored in massive rock and brittle rock masses. In the event of secondary stress arising from excavation, the sudden release of this energy results in new fractures in the zone near the excavation void and on the excavation walls. In unsupported sections, the sudden release of energy in excessively brittle rock can cause rock bursts and ejection. Fractures in the rock mass extend deeper over time. Excessive water flow into weathered or disintegrated rock mass has a significant effect on the rock mass’s strength.

Excavation should proceed in sections. A bottom excavation is required. The advance step length shall not exceed 1.5–2.0 m in the upper half and 3 m in the lower half. Excavation may be carried out using controlled blasting or mechanical excavation methods.

Short but densely spaced rock bolts and steel mesh are required as support elements. As an additional measure, pressure-reducing holes may be drilled into the rock mass. This method can

also prevent rock bursts. Depending on geological conditions, it may be necessary to construct a cast-in-place base arch concrete structure no more than 50–75 m behind the upper bench face. The support system will be shown in detail in the project documents.

C2 Support Class: This is referred to as a ‘compressed’ rock mass. C2 is characterised by plastic zones extending deep into the surrounding rock mass and a pressure-generating behaviour. In this rock mass, moderate but distinctly prolonged deformations that subside slowly are observed. The magnitude and rates of deformation around the excavation are moderate. Stress is observed in high-cohesion rock masses exhibiting plastic behaviour. Water seepage and concentrated water flow have a significant effect on the rock mass.

The tunnel excavation must be divided into upper half, lower half and base excavation. Except for special cases in portal areas, the upper half excavation will be subdivided internally. A support structure will be required in the face of the upper half excavation. The advance step length will not exceed 0.75–1.25 m in the upper half and 2 m in the lower half. Excavation may be carried out using controlled blasting and mechanical excavation methods. A shotcrete lining is required immediately after cutting.

The tunnel face is generally stable. Systematic support is required around the entire cross-section. Progress to the next advance step will only be permitted once the support system has been completed for each advance step. A continuous lining application will be required on the tunnel roof. For the application of the lining, drilling sequences and subsequent construction must prevent adverse effects on the rock mass in the face and roof. The function of the support elements is to limit deep plastic fractures. A base arch is required, situated no more than 50 m behind the upper half of the face, in accordance with geological conditions. The support system will be shown in detail in the project documents.

C3 Support Class: “Highly stressed” rock mass. C3 is characterised by the formation of deep zones of weakness, initially high and rapid deformations. Deformations persist for a long time and subside slowly. Fractures and plastic zones extending into the depth are observed. Water seepage and concentrated water flow have a significant effect on the behaviour of the rock mass.

The tunnel excavation must be divided into upper half, lower half and floor excavation. A support structure will generally be required in the upper half excavation face. Systematic support may be required in the face. The advance length shall not exceed 1.2 metres in the upper half and 2.0 metres in the lower half. Excavation will generally be carried out using soft blasting or mechanical excavation methods. A shotcrete lining is required immediately after blasting. A dense support pattern will be required across all excavation faces. Special arrangements will be required, such as the use of support elements capable of responding to deformation levels, deformation voids and/or large deformations. The support elements will maintain the triaxial stress state of the rock mass. Should shortening the advance step length, extending the bench length, and leaving a large central support body in the upper bench prove insufficient, the bench excavation may need

to be further subdivided into lower sections. Possible solutions include carrying out the upper half excavation in half-sections or side galleries. Should the excavated section exhibit excessive vertical movement, it may be necessary to widen the lining foundation, bolt and grout the base region of the shotcrete shell, or install temporary floor arches.

All tunnel support is systematically installed prior to further advancement of the upper and lower half excavation faces. The use of a continuous pipe will be required across the entire roof section. The adverse effects of drilling or similar operations on the rock mass at the face or roof will be prevented. In the upper half excavation, cross-sections divided into lower sections and temporary ring structures may be required. Ring closure of the floor arch may be required 25–50 metres behind the upper half excavation face. The support system will be shown in detail in the project documents.

C4 Support Class: This is referred to as a ‘flowing’ rock mass. Very low cohesion and friction, combined with the rock mass’s low plastic behaviour, cause material to flow into the tunnel even in a split excavation left unsupported for a short time. Low cohesion necessitates numerous sub-divisions in the excavation. The ground has no self-supporting period unless pre-tunnelling installation is carried out or sprayed concrete lining is applied simultaneously with the excavation. Water seepage and concentrated water flows may have a significant effect on the behaviour and properties of the exposed ground. Therefore, measures to improve the strength of the rock mass may be considered. To prevent stability issues in the tunnel face, subdivision into side galleries will be necessary. Additionally, support structures are required for the upper half of the excavation. It is possible to allow for limited excavation thanks to the supporting effect of the tunnel face, achieved through advance support or special support measures. The advance length will not exceed 1.5 m in the upper half and 2.0 m in the lower half. Excavation will be carried out using a tunnel excavator. Shotcrete lining is required in conjunction with the excavation.

Tunnel support must be completed in each advance step in both the upper and lower halves. The installation of steel pipes or steel plates will be required for the majority of the roof section. A support system comprising shotcrete, steel mesh, rock bolts and drainage elements may need to be used on the excavation face during or immediately after excavation. Sprayed concrete lining must be carried out in conjunction with the excavation of the section divided into subsections. The installation of a lining is mandatory. Temporary ring closure may be required in the subsections of the upper half excavation. Ring closure in the base arch may be necessary over short distances of between 25 and 50 metres behind the upper half excavation face. The support system will be shown in detail in the project documents.

Support Class C5: This is referred to as a “highly cohesive, short-term stable” rock mass. In rock masses containing swelling-prone clay minerals, salt or anhydrite, loosening occurs due to volume expansion caused by water absorption. By limiting free openings in the arch and face, the rock mass can remain stable for a limited period. Seepage and concentrated water flow have a

significant effect on the behaviour and properties of the excavated ground. Swelling may have been initiated.

The excavation must be divided into an upper section, a lower section and a base excavation. In many cases, a support structure will be required for the face of the upper section excavation. The advance lengths shall not exceed 1.5 metres in the upper section excavation and 3.0 metres in the lower section excavation. Excavation may be carried out using a tunnel excavator. Blasting may be required when excavating large rocks or locally hard rock sections.

Tunnel support must be completed in each advance section in both the upper and lower halves. The installation of continuous pipe or steel sheet piling will be required for the majority of the roof section. Sprayed concrete lining must be applied in conjunction with the excavation of the section divided into lower sections. A base arch is required, not more than 25 metres behind the upper half face, in accordance with geotechnical requirements. The support system will be shown in detail in the project documents.

Based on the data obtained from on-site and laboratory tests conducted on the boreholes and core samples taken along the tunnel route, the tunnel is classified into the various rock classes defined above in accordance with ÖNORM B 2203 . For each rock class, the excavation system will involve the design of primary support elements (shotcrete, steel mesh, steel shoring, struts, bolts, etc.) and secondary support elements (lining concrete).

The rock/soil encountered during tunnel construction along the tunnel's length will be classified for the purposes of excavation and support, and the following sequence will be followed in the preparation of the excavation/support design schemes.

- Based on the strength and physical parameters of the rock/soil defined for different rock classes in the geological-geotechnical report, the types of support to be used (shotcrete, steel shoring, bolts, etc.), material parameters, excavation geometry, and fundamental information such as the excavation environment affected by the excavation and overburden load, a separate calculation model will be created for each rock class.
- The design of tunnel supports and excavation stages will be finalised using numerical (Finite Elements, Finite Difference, Boundary Elements) and analytical calculations (Hoek and Brown). In these calculations, it must be possible to model unsupported and supported excavation stages depending on the rock class, the tunnel geometry, and different material compositions (bolts, shotcrete, etc.) as required during tunnel construction. The following conditions must be taken into account in the calculations.
    - Initial stress conditions (provision of stresses arising from the tunnel's own weight in the environment where excavation is to take place prior to excavation)
    - Final excavation condition (the condition prior to post-excavation shoring, or—in the case of phased excavation—the condition following the completion and shoring of the previous phase, for each excavation phase)

- Final state of primary support (for the final condition where all supports have been installed along the tunnel cross-section)
- The interaction between excavation and support works for the two tunnel tubes, carried out in conjunction with the excavation support stages, shall be taken into account. The interaction between the excavation works to be carried out in the tunnel tubes, both in the same plane and in the longitudinal direction, shall be examined in the calculations.
- Final condition (the final state after the concrete finish has been applied and, where applicable, the effects of groundwater have been taken into account)
- The lining concrete shall consist of impermeable concrete with a thickness of not less than 30 cm and, unless otherwise required (as different approaches may be necessary due to factors such as groundwater, shallow overburden thickness above the tunnel, potential landslide areas, soft ground, or built-up urban areas), It shall contain reinforcement equivalent to at least 0.15% of the cross-sectional area. The reinforcement shall be placed symmetrically within the cross-section. For example, in a cross-section where the lining is 40 cm and the cover is 5 cm, 35 × 100 × 0.15/100 = 5.25 cm² of reinforcement must be placed on each face of the cross-section. Minimum reinforcement helps to limit the stresses caused by crack formation in the reinforcement and to reduce crack width (the crack width should not exceed 0.2 mm). In concrete with a cover of , the compression zone should not be less than 15 cm. Furthermore, the contact injection pressure behind the cover concrete and the minimum strength required for formwork removal during construction must be calculated.
- Calculation reports must include programme outputs showing all necessary calculation criteria, calculations and values used in the design.

- Based on the results of the calculations regarding the excavation and support system (bolt spacing, length, sprayed concrete thickness, etc.), standard support designs and standard excavation and support sequence designs will be prepared.
- The calculations specified above will be carried out for the sections where pedestrian and vehicular crossings between the two tubes are located, and care will be taken to select sections where rock and ground conditions are suitable. Standard support and excavation designs will be provided for such crossings.
- Special excavation and support designs must be prepared for sections where water-bearing soil/rock layers are expected to be encountered in the tunnels.
- The excavation method and equipment to be used during construction works in the tunnel will be determined for each rock class. Furthermore, a blasting pattern will be designed for rock classes where blasting excavation is recommended.
- A geotechnical monitoring programme and typical monitoring sections will be prepared during the design phase to enable the control of deformations, settlements and stress increases taken into account during the design process. Typical measurement sections will provide the necessary details specifying the required number and locations of measurement points, depending on the rock classes. The deformation quantities

determined as a result of the excavation and support design for each rock class, along with construction and unavoidable excavation tolerances, will be presented in tabular form on a separate sheet, incorporating changes in the tunnel excavation geometries.

5.12.1.5. TBM Tunnels

The analysis and design of components used in tunnels excavated by TBM (Tunnel Boring Machine) shall be carried out in accordance with the rules specified in this section.

The tunnel design commonly used in railway systems comprises a structure consisting of six segments, each 1.50 metres long, with an inner ring diameter of 8.6 metres and a tunnel lining thickness of 30 centimetres. Four of these segments are arranged in parallel, whilst the other two are designed in a trapezoidal shape (one being the key segment and the other the counter-key segment).

General Tunnel Design Principles:

- Ensuring that all temporary and permanent construction phases proceed in a balanced and robust manner.
- Designing structures to acceptable standards to ensure they are operational.
- Design to minimise environmental impact (with a particular focus on limiting effects on buildings and groundwater).
- Working without causing damage to existing infrastructure services and underground utilities.

Segment Lining Characteristics

The tunnel lining will fulfil the following functions during operation:

- Act as a permanent tunnel lining to support environmental constraints.
- Providing the necessary protection to ensure the continuous and permanent suitability of the tunnel's working clearance.
- Provide support for fixed and portable equipment intended for permanent service.
- Provide adequate waterproofing properties through a suitable waterproofing system between the segments.
- During the tunnel construction phase, the segment lining will perform the following functions:
- Provide direct support to the excavation.
- To enable the TBM to advance by excavating the ground whilst providing longitudinal support.

Geotechnical Information

The geotechnical parameters of the materials will be determined in geological and geotechnical reports based on the results of laboratory and field tests.

Mixed ground assessments will be carried out, taking into account the possibility of different soil types being present within the same tunnel cross-section.

Geotechnical models will be supported by ground investigations, and design calculations will be carried out based on information provided by geological profiles and geotechnical reports.

For tunnels excavated within rock masses, the Hoek-Brown failure criteria will be used. Rock mass parameters will be derived from equations based on the Geological Strength Index (GSI).

Given that values such as RMR and the Q-system may be meaningless for weak and heterogeneous rock masses, the GSI table—which is fundamentally qualitative—will be used to determine the geological strength of rock masses (Hoek-Brown, 2018).

Determination of Geotechnical Parameters

Soil parameters will be calculated in accordance with ITA (International Tunneling Association) guidelines and Turkish regulations, as well as the European Standard Eurocode 7, for the relevant tunnel cross-sections. This calculation process will take into account the combination of the most adverse conditions, such as water levels and overburden geometry. The parameter set given below will be defined at each selected point:

- Ground level (m), Groundwater level (m), Track top elevation (m)
- Coefficient of lateral earth pressure at rest (K_0)
- Modulus of elasticity (E)
- Poisson's ratio (v)
- Cohesion (c)
- Angle of friction (ϕ)
- Wet/dry unit weight of the soil (γd)
- Saturated unit weight of the soil (γ_{sat})

Excavation and Support Method

In mechanised tunnel excavation applications, a balanced excavation process is carried out using Tunnel Boring Machines (TBMs) that maintain pressure at the face. The tunnel linings consist of precast reinforced concrete segments with pre-installed support, which are placed by the machine immediately after excavation. The continuity condition is always ensured by the following factors:

- It will be balanced by the pressure applied by the TBM.
- The excavation boundaries will always be supported by first installing a shield, followed by precast segments arranged in a ring.

Segment Structural Material Properties

The design of the concrete segments shall comply with at least C40 concrete class. Weldable S420 grade steel shall be used for the reinforcement cages of the segments. The concrete quality of the segments will be assessed in accordance with Eurocode 2 standards, taking environmental effects into account, and confirmed as suitable. Furthermore, the dimensions of the segment formwork will be checked at regular intervals, and detailed information on this matter will be provided in a separate document.

Loads and Load Combinations

During the analyses, the acting loads can be classified as follows:

- Permanent loads
- Operational loads and exceptional loads (Accidental Loads)
- Variable loads

Generally, several load cases will be considered during the design and construction phases to account for all temporary, permanent and accident conditions:

A. Temporary loading conditions:

- Demoulding
- Storage
- Transport

B. Construction load condition:

Segments subjected to the lifting operation of the segment lifter and exposed to the thrust force of the TBM

C. Service load conditions

- Horizontal and vertical ground pressure
- Water pressure
- Self-weight
- Overload effects
- Soil reaction

D. Other loading conditions

- Effects of constructing two or more tunnels
- Effects of constructing a connecting tunnel
- Seismic conditions
- Fire loads

The following loading conditions will be used in the calculations:

- Ground pressures
- Additional loads arising from buildings, approximately on the surface are applied as distributed loads; unless further investigation is carried out, a floor load of $15\ kN/m^2$ will be assumed for the buildings.
- Dead loads on support elements and reinforced concrete elements
- Full hydrostatic groundwater pressure
- Seismic loading shall be added.

Loads arising from buoyancy shall be assessed for the most unfavourable groundwater levels expected over the design life. Buoyancy loads shall be treated as additional permanent loads.

▪ Permanent Loads

Soil loads (P) – Soil loads are determined based on the specified critical conditions. To evaluate the loads acting on the tunnel lining using an elasto-plastic method, it is necessary to define a certain degree of soil relaxation or the equivalent 'Volume Loss'.

The characteristics and dimensions of the TBM will be taken into account when defining volume loss. During the EPB tunnelling process, the total ground loss arises as a result of the soil pressure applied to the face, the shield dimensions, and the grouting carried out to fill the void formed between the excavation face and the segment.

To simulate the weight of any potential rock wedges above the tunnel, additional loads in the rock mass may be taken into account.

Water pressure (W) – Water pressure will be treated as an elliptical circular load in the structural model.

Surface loads (Ps) – When the tunnel passes through an urban area, traffic loads will be considered with a minimum additional load of 15 kPa on the ground surface. Current and future conditions will also be taken into account.

Dead Weight of the Lining (Pp) – The dead weight of the lining will be taken into account based on its geometric and material properties.

▪ Operational Loads and Exceptional Loads (Random e Loads)

- Earthquake loads – The deformations caused by seismic effects in the lining will be analysed, and specific investigations will be carried out for this scenario.
- Secondary injection pressure (G) – The effect of the secondary pressurised injection to be carried out at the upper end of the tunnel ring, parallel to the excavation, on the segment lining will be taken into account as shown below (injection pressure forming a 60-degree arc to the tunnel ring).

▪ Variable Loads

In addition to the above loads, the storage, lifting and manufacturing stages will also be taken into account in accordance with ITA. Each segment type will be analysed individually for lifting, transport and storage conditions. The concrete strength and the relevant modulus of elasticity will be selected to account for the concrete's age and strength at each stage. Variable loads include the following:

Loads applied during manufacture (demoulding) – This load condition takes into account the minimum compression during the demoulding of the segment. The geometry is that of a single segment. The load considered comprises the segment's own weight plus a dynamic load factor for lifting.

Loads applied during storage – For the storage of the segment, the optimum distance between supports will be calculated. This calculation will be carried out to ensure a minimum compressive force following demoulding. For the storage of all segments, account will be taken of the fact that all segments will be stacked during transport. The eccentricity of the support between the bottom segment and the second segment will be taken into account.

Loads applied during segment installation – During ring installation, the segments will be subjected to load conditions similar to those experienced during lifting and storage at the precast plant.

The loads applied during the shoving process, particularly those applied to a single segment using a shoving ram, are a significant factor in tunnel design. These loads will be taken into account both during the shoving process and to determine the size of the reinforcement in the contact zones between segments. In fact, as these high-intensity loads are applied to relatively small surfaces, they can typically influence a specific stress state—often accompanied by tensile and compressive stresses in a plane perpendicular to the direction of the applied thrust. Therefore, particular importance will be placed on determining these loads by taking into account their effect both during normal operating conditions (i.e., the EPB machine's normal operating conditions) and during the potential maximum thrust (in accordance with the project-specific EPB Shield Specifications prepared by experts based on the project's specific requirements).

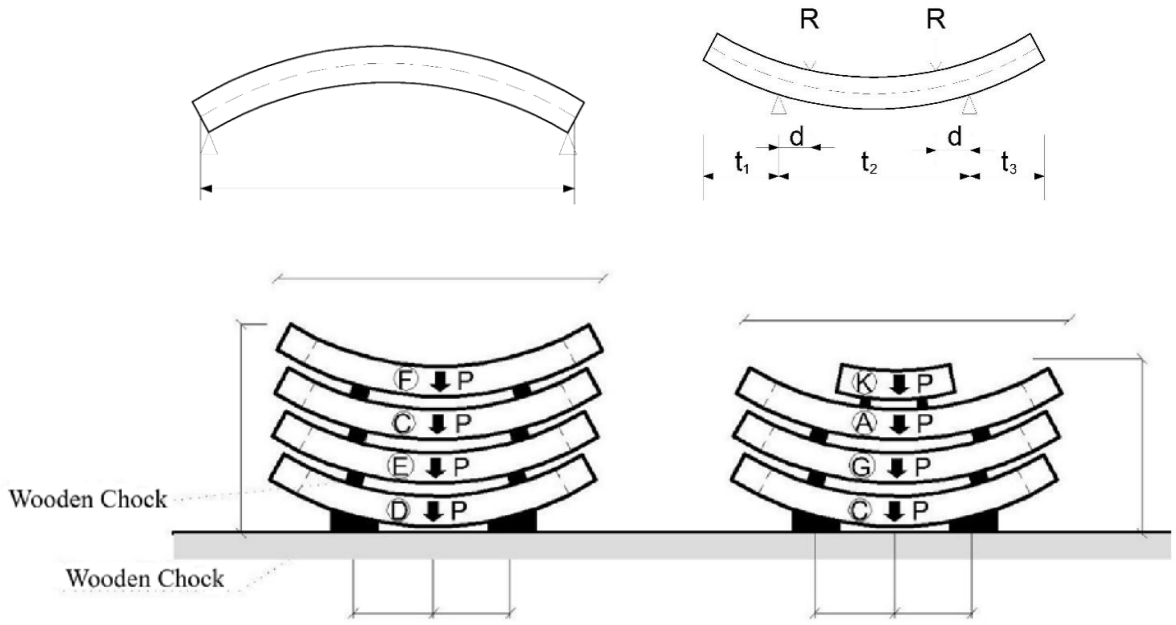


Figure 5.13 : Typical scheme for formwork removal, storage and transport (example)

▪ Load Combinations

During tunnel construction, the relevant mandatory regulations and the rules of the European Standard Eurocode 2 will be taken into account.

Pp: load resulting from the structure's own weight.

P: Ground loads acting on the perimeter of the lining.

W: Hydrostatic load caused by groundwater.

Ps: soil surcharge load.

G, the temporary load caused by pressurised backfill.

Load condition under the effect of the Operational Design Earthquake (ODE)

Load condition under the influence of the Maximum Design Earthquake (MDE)

In addition, a condition analysis corresponding to the pile driving operation will be carried out, and both the loads during driving and those on the rear side will be taken into account to assess the current condition of the reinforcement.

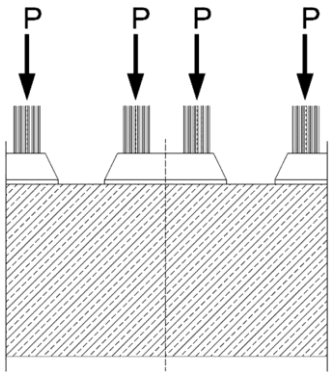


Figure 5.14 : Thrust load distribution (ITA)

Selection of Critical Sections

An assessment will be carried out by considering combinations of worst-case scenarios, such as ground loads, water pressure, overburden loads and ground parameters, and by calculating the effects of the second tunnel excavation on the lining of the first tunnel.

In addition to selecting specific cross-sections where geology may vary and could lead to significant consequences, the following critical conditions may need to be assessed through numerical calculations:

1. Scenario: The scenario where the overburden thickness is at its maximum.
2. Scenario: The scenario where the overburden thickness is at its minimum.
3. Condition: The condition where the groundwater level is at its highest.
4. Condition: The condition where the groundwater level is at its lowest.
5. Condition: The section or sections where large overburden loads are present.
6. Condition: Sections subjected to eccentric loading.
7. Condition: Sections where the ground surface is uneven.

8. Condition: Sections where adjacent tunnels currently exist or where the construction of adjacent tunnels is planned in the near future.

9. Condition: Sections where interaction with existing and nearby infrastructure may occur.

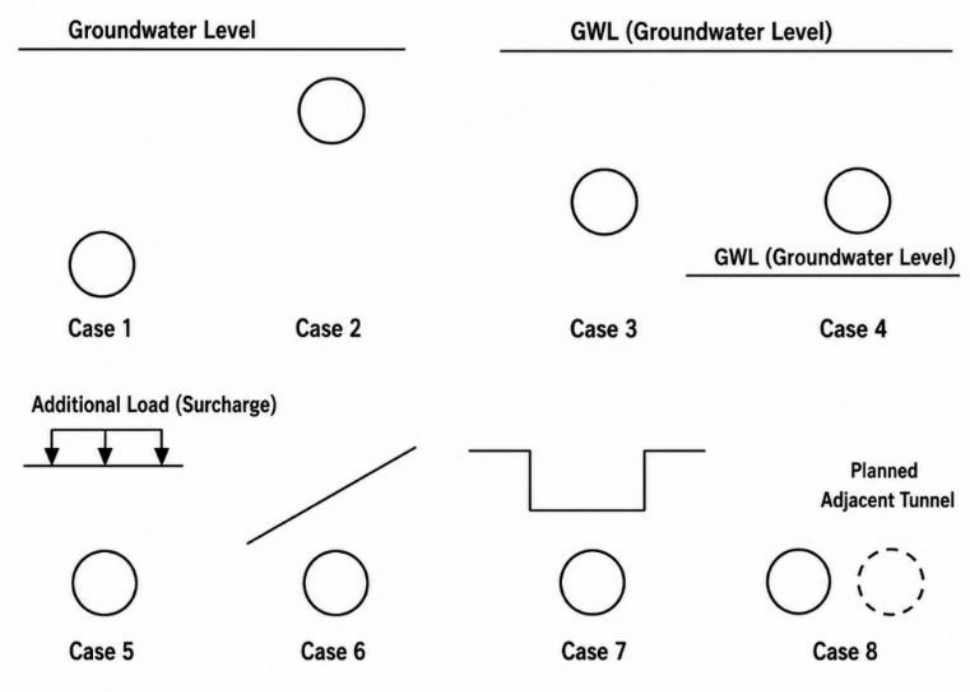


Figure 5.15 : Critical sections (ITA) to be checked in the segment lining

Minimum Impact Area

The minimum influence zone is defined in the trapezium shown in the critical figure at Figure 5.27. It consists of two points on the surface, each located at a maximum horizontal distance of three times the tunnel's maximum axial width (D) on either side of the tunnel axis, and two points on the subgrade, located 5 m below the tunnel crown and on its horizontal tangent.

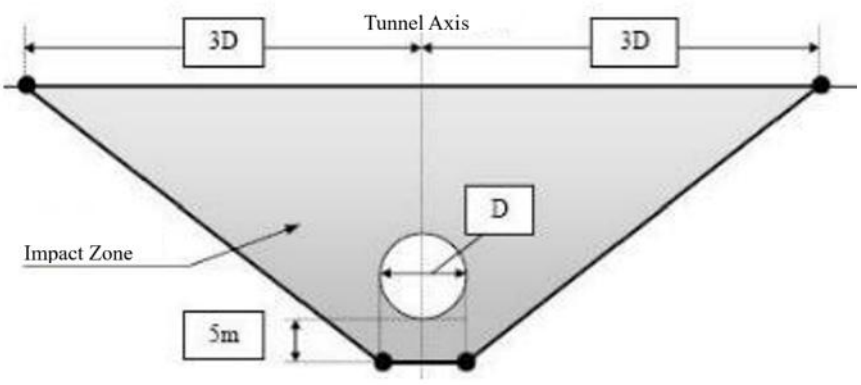


Figure 5.16 : Minimum influence zone

Structural Analysis Method

Internationally recognised software utilising the structural finite element/difference method will be used to calculate forces such as bending moment, axial force and shear force in the segments.

These software packages have been specifically developed for geotechnical simulation and must be capable of simultaneously simulating both soil reaction and the structural behaviour of the segment. Two-dimensional analysis can be performed for general cases. The plane-strain approach is a commonly used engineering assumption for this type of problem.

The various stages of excavation will be simulated. Furthermore, in the event of volume losses, these losses can be simulated as tunnel shrinkage expressed directly as a percentage.

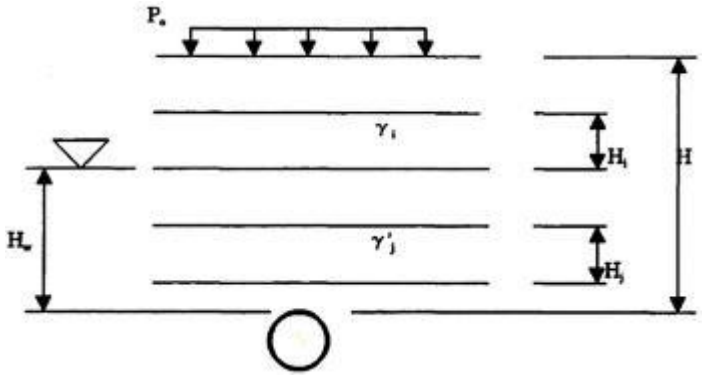


Figure 5.17 : Typical load analysis for tunnels

Ring Modelling

Each segment will be modelled using beam elements defined at the four corners and joined together to form a real geometric shape.

Calculation Stages

The continuity model calculation will be carried out step by step as follows:

The primary stress state (in-situ stress Po) will be defined in accordance with geotechnical soil parameters.

Subsequently, the excavation of the first tunnel will be simulated by removing the internal pore pressure and soil elements. The lining elements will be activated. In the event of volume loss, this loss will be defined as the applied shrinkage percentage recommended by the software developer.

The excavation of the second tunnel will also be carried out based on the same procedure.

In twin tunnels excavated in weak geological formations, where the distance between the tunnels is <2D and the overburden thickness is <2D, it is theoretically known that the second tunnel, which is excavated later, will be excavated under weaker ground conditions due to the disturbance caused by the tunnel being excavated first. In such cases, it is important to take into account the disturbance caused in the ground conditions when estimating the cumulative settlement that the second tunnel will create at the surface.

The analysis results will be presented in detail, including the following information:

- Detailed vertical and horizontal stress diagrams obtained using the finite element/difference method.
- Stress conditions around the excavation.
- (If applicable) plasticised soil elements.

Structural Analysis Results

The relevant displacement values for each node and the bending moment, normal force and shear forces for each element will be reported. These forces will be used for structural checks/analyses.

The following data will be included in the foundation design:

- Deformed shape.
- Bending moment distribution.
- Normal force distribution.
- Shear force distribution.

Analysis of Specific Cross-Sections

As in the case of connection tunnels, suitable software tools can also be used for specific modes. In such cases, the structure's interaction with the ground can be modelled using springs in the radial direction. The stiffness of these springs will be proportional to the influence area of each node and the elasticity coefficient of the ground. The ends of the spring elements will be connected to the nodes of the shell structure (displacement only) and fixed at the other end.

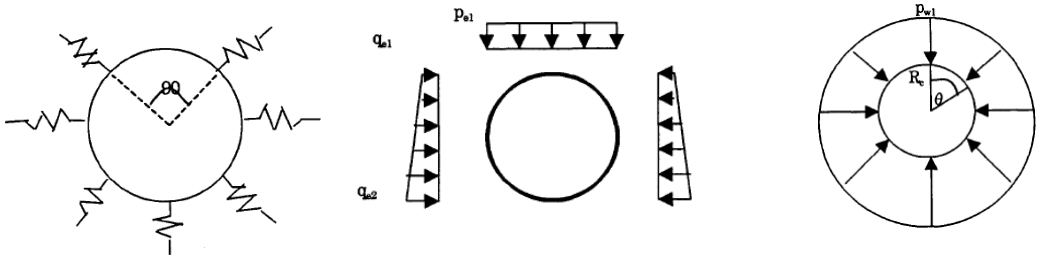


Figure 5.18 : Example of modelling and load effects

Modelling of soil reactions using independent radial springs will involve calculating the distribution of soil and hydrostatic pressures acting on the tunnel lining.

Structural Checks/Analyses

Segments: These will be examined to evaluate normal force, bending and shear effects under all analysis conditions (including temporary loads).

Circular Joints: These are the joints between segments within the same ring and allow the transmission of ground loads. These contacts will be checked and verified against opening and pressure forces. Tensile forces at the joints will be calculated based on detailed analysis results.

Radial Joints: The reinforcement's role in transmitting axial forces at segment joints and sharing TBM excavation loads will be examined.

Crack Analysis: Serviceability Limit State (SLS) crack widths will be limited to 0.2 mm for the relevant load combinations in accordance with Eurocode 2.

Fasteners and Bolts: For safety reasons, fasteners and bolts will be checked against the worst-case scenario during production. Additionally, gaskets will be tested under operating conditions to ensure watertightness.

TBM Support Structures

TBM support structures shall be constructed from steel sections or, where necessary, as reinforced concrete. Two different types may be used for the thrust structures to be constructed within the tunnel and in the cut-and-cover sections. For the design of TBM thrust structures, the loads transmitted from the TBM pistons will be taken into account; necessary measures will be taken to ensure these loads are safely transferred to the foundation or temporary lining; and the calculation reports and designs will be submitted for approval separately.

TBM Pushing in the Platform and Switch Tunnels

At the TBM entry and exit portals, designs suitable for the TBM's dimensions and thrust frame geometry will be prepared, and these designs will be taken into account in the excavation and shoring designs as well as the formwork plans.

During the design of the cut-and-cover stations to accommodate TBM passage, the raft slabs will be arranged with an elevation and bedding geometry suitable for the TBM's outer diameter. Similarly, the necessary details will be submitted for approval by creating the appropriate geometry in the crossover tunnels.

Precast/Steel Walkways and Insulation

For precast/steel walkways, the installation of rebar in segments, mechanical/chemical dowel anchoring and the use of ground bolts may be required.

The rebar insertion work will be carried out with care to ensure that existing reinforcement is not cut.

In the method involving the use of ground-anchor bolts, the relevant bolts must be left in place within each precast segment and used to secure the walkway to the appropriate point.

The appropriate system will be selected during the precast segment design phase, and the relevant details will be submitted for approval.

Joints between precast segments and station and crossover tunnels will be designed to be watertight; the relevant details will be submitted for approval separately.

Reference Documents

- FHWA Technical Manual for the Design and Construction of Road Tunnels – Civil Elements
- ITA Guidelines for Shield Tunnel Lining, “Tunnel and Underground Space Technology”
- Seismic design and analysis of underground structures, ITA publication “Tunnel and Underground Space Technology”
- AFTES Recommendations for the Design, Sizing and Construction of Precast Concrete Segments to be Mounted Behind the Tunnel Boring Machine (TBM)
- AFTES Guidelines for the Seismic Design and Protection of Underground Structures
- Turkish Standards for Concrete Materials and Concrete Construction Methods
- “AFTES Recommendation for Segment Joints”

5.12.1.6. Design of Portal Sections

The design of tunnel portal sections will encompass design studies relating to the design of the face (wall) and side portal slopes, and the creation of suitable excavation conditions to commence tunnel excavation safely in portal excavation sections located beneath the tunnel’s thin cover. The following studies will be carried out in sequence and reports prepared.

- In order to carry out the tunnel portal design, the necessary investigative works to facilitate the design in the portal areas must have been completed. Stability analyses and designs of the portal face and side slopes will be carried out using the engineering parameters obtained from these works.

To this end, a specific geological-geotechnical report for the portal sections will be prepared. This report will include a plan and data package detailing all portal investigation works carried out. These reports will contain plans, profiles and cross-sections illustrating the geological-geotechnical structures of the portal and side slopes. The geological and geotechnical investigation works included in the report will be evaluated, and soil/rock parameters relevant to slope stability calculations, along with other predictions (such as kinematic analysis results, etc.), will be provided. The reports will also include all data considered in slope design (soil/rock strength parameters, slope height, loading conditions, etc.) and all analyses to be carried out to determine the geometry of the slopes (stability analyses such as planar, circular and wedge-type sliding, etc.). In the portal sections, the design of the portal slopes will be studied with alternatives, following a specific assessment of the presence of stable rock conditions in the section where tunnel excavation is to commence, the thickness of stable rock, the conditions at the portal entrance, and the necessary measures to be taken. Should slope support be required, support calculations (shotcrete, anchors, pile walls, etc.) will be included in detail in this report. The design of the slopes will be carried out for both short-term and long-term static conditions, as well as seismic conditions. Safety factors will be considered as 1.5 for peak parameters and 1.3 for residual parameters in the long-term static condition; 1.3 for peak values in short-term stability; and 1.1 in the seismic condition.

- Portal structures will be designed for traffic safety at the portal sections of the tunnels. In the design of portal structures, the general topographical conditions of these areas, the location of the slopes and environmental factors (urban, rural, etc.) must be taken into account. The structural and reinforced concrete calculations for the portal structures, along with the necessary drawings, will be provided.
- Where portal structures such as opening-closing mechanisms and flutings are required in the portal sections of the tunnels, the relevant calculations for these structures will be provided within the scope of the same report. The structural calculations will be carried out for different load conditions (dead load, live load, seismic load and earth pressures).
- The support measures to be taken at the initial tunnel face created to commence tunnel excavation in the portal sections will be designed in accordance with the results of the studies mentioned above. Temporary protective arch (canopy) structures will be designed to ensure safety during construction in these sections.

Within the scope of the portal projects;

- portal excavation plans, cross-sections, longitudinal sections and elevations,
- support details for portal faces and side slopes,
- cross-sections, formwork and reinforcement details of the portal structures,
- details of the canopy structure, and
- drawings showing details of other structures that may arise from the characteristics of the portal area

will be prepared.

5.12.1.7. Tunnel Clearance Calculation

The minimum cross-sectional area of new tunnels must prevent temporary pressures generated by non-pressurised trains passing through a tunnel without ventilation shafts, airlocks or junctions from compromising passenger comfort. Consequently, any such pressures will be kept within limits.

The calculation of the clear space within the tunnel is based on the methods set out in the publication entitled "International Union of Railways-UIC Code / 779-11: Determination of railway tunnel cross-sectional areas on the basis of aerodynamic considerations". The inputs used in the calculation are given below:

- Maximum permitted speed within the tunnel
- Tunnel length
- Train length
- Train area: The train area varies between 10 and 12 m². The train area can be defined as the area between the outer lines delimiting the train when the train cross-section is considered. This definition is illustrated in the drawings below:

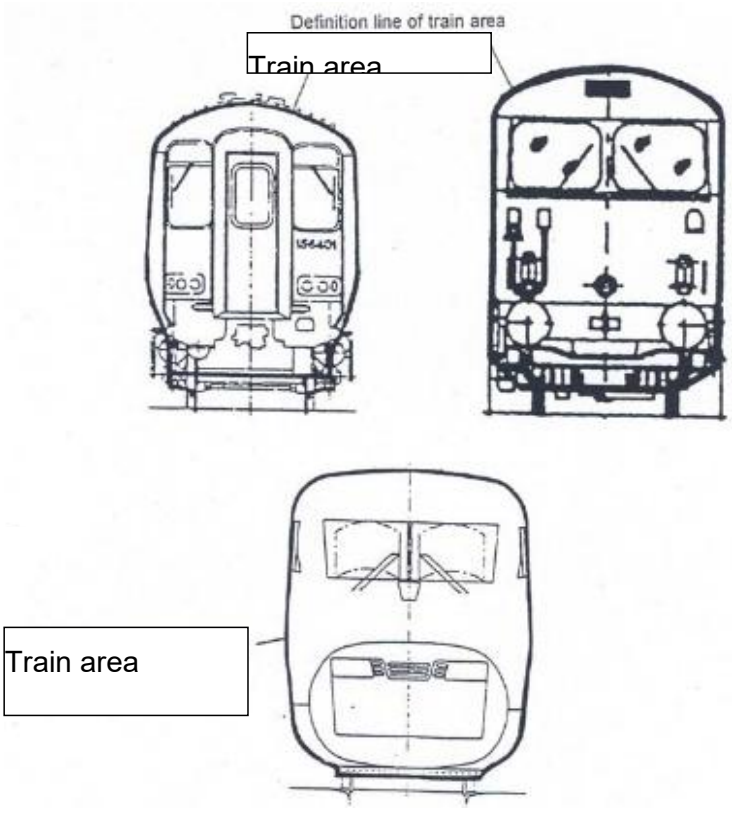


Figure 5.19 : Train area

- Permitted maximum pressure variation: The maximum pressure variation (defined as the difference between positive and negative pressures) generated by the train whilst travelling at the permitted maximum speed within the tunnel must not exceed 10 kPa. This value is specified in the Council Decisions of 30 May 2002, which refer to the 'Council Directive of 23 June 1996 on the operation of the trans-European high-speed rail network', published in the Official Journal of the European Union on 12 September 2002.
- Internal clear space: The definition is provided in the diagram below;

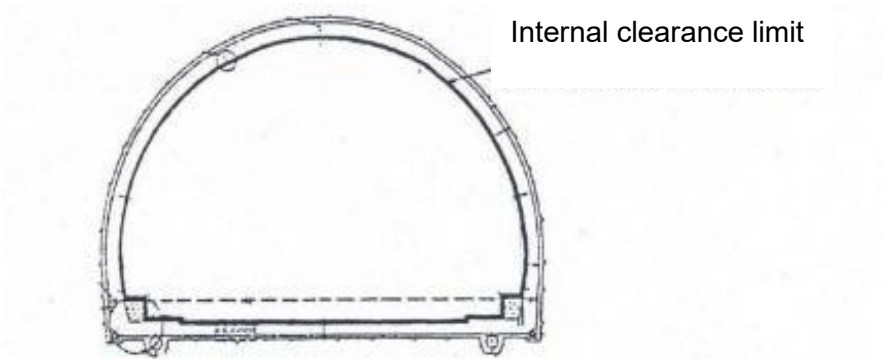


Figure 5.20 : Tunnel clearance limit

- B: The ratio between the train area and the tunnel clearance. It is derived from graphs illustrating the relationship between the maximum permitted speed within the tunnel and the 'maximum permitted pressure variation'. The graphs are provided at the back of UIC Code / 779-11.
- Tunnel traffic type

To determine the train cross-sectional area, the appropriate graphs for the relevant traffic type, vehicle type and maximum permitted speed within the tunnel are selected in accordance with UIC Code / 779-11. Subsequently, the point where the ratio of (Tunnel length) / (Train length) intersects with the permitted maximum pressure variation within the tunnel on the graph is identified, and the "B: Ratio of train area to internal free space" is calculated. Once this has been calculated, the cross-sectional area of the train to be used within the tunnel is divided by this value to determine the "internal free space". If the ratio of (Tunnel length) / (Train length) falls outside the values specified in the graphs, the internal free space of the tunnel must be calculated using specialised computer programmes.

5.12.1.8. Safety in Tunnel Design

General

The safety measures to be taken in railway tunnels are listed below in order of priority:

- Prevention of Accidents
- Minimising damage resulting from accidents
- Facilitating evacuation
- Facilitating rescue operations

The safety measures specified in the following sections are applicable to tunnels ranging from less than 1,000 metres in length up to 15 kilometres. However, special safety measures may be required for tunnels longer than 15 kilometres.

All necessary safety measures are comprehensively outlined in “UIC 779-9 / Safety in Railway Tunnels” and in publication “TRANS/AC.9/9” dated 1 December 2003 by the Transport Committee of the European Economic Commission, affiliated with the United Nations Economic and Social Council.

The safety measures listed below define the minimum measures that must be taken in tunnels:

- Speed control, monitoring and signalling system
- Periodic inspection of tunnels
- Fire protection measures
- Derailment control measures
- Fire protection requirements for structures
- Train radio
- Cancellation of the emergency brake and ensuring continued movement
- Removal of the train from the tunnel
- In the event of an incident within a tunnel, preventing other trains from entering the tunnel and ensuring the controlled evacuation of trains already inside
- Emergency escape walkways
- Installation of handrails at appropriate heights on tunnel walls
- Tunnel signage
- Tunnel emergency lighting
- Training of railway staff
- Water supply for firefighting and rescue services
- Installation of a radio system for rescue services
- Reliability of the electrical system
- Emergency and rescue plans
- Drills for rescue services
- Information regarding the transport of hazardous materials

If any of the minimum safety measures specified above cannot be implemented, but the desired safety level within the tunnel can be achieved only by combining other measures, this may be permitted.

5.12.1.9. Seismic Design of Tunnels

Earthquake design shall be carried out in accordance with the “Regulation on Earthquake Design of Road and Railway Tunnels and Other Ground Structures in Turkey”, published in the Official Gazette on 06.10.2020.

5.12.2. Ground Improvement

In selecting the appropriate type of ground improvement to ensure a safe and effective excavation and construction method, the following factors shall be taken into account:

- Soil classification and stratification procedures
- Pore water pressures and drainage characteristics
- Excavation dimensions
- The duration for which the excavation may remain open
- The type and proximity of adjacent structures

Soil improvement refers to various soil improvement or reinforcement techniques and may include (for illustrative purposes only and without limitation):

- All types of ground stabilisation injections (cement slurry, chemicals, etc.)
- The jet-grouting method (improvement of soil properties by means of high-pressure air/water and cement injection)
- Permeable grouting
- Compaction grouting
- Balancing grouting
- Ground freezing
- Pile placements
- Stone columns
- Aggregate-filled shallow foundations
- Soil replacement, etc.

Quotations for ground improvement will be provided, accompanied by detailed justifications and necessary calculations where required.

5.12.3. Building Risk Analysis (BRA)

5.12.3.1. General

The accepted and applicable methods for the settlement assessment and protection of buildings situated on or adjacent to new railway lines will be clearly defined.

Whilst the necessary explanations are provided below, the acceptance criteria for structural and non-structural elements (such as architectural cladding, walls, etc., and damage to brittle elements in terms of architecture and functionality) set out in the FHWA Technical Manual for Design and Construction of Road Tunnels – Civil Elements, as well as TS EN 1997-1 and TS EN 1997-2, shall be taken into account. These analyses will be carried out for both railway tunnel excavation and excavation shoring scenarios.

A proper tunnel design within an urban area will include specific risk assessments for buildings and infrastructure units located within the impact zone of railway excavation works; such assessments:

- Building-specific research and archive searches
- Determination of the internal vulnerability index of a building or infrastructure facility based on all available information
- Estimation of settlement caused by the excavation in relation to each building
- Identification of potential damage (architectural, functional and structural) based on possible crisis scenarios
- Includes the processes for planning relevant countermeasures or final preventive protection works.

The process of determining the risk of damage to connected buildings due to potential settlement caused by tunnelling works essentially consists of two groups of activities:

- **BCA (Building Condition Assessment)** aims to inspect the actual conditions of buildings within areas affected by construction, before, during and after tunnel construction works
- **BRA (Building Risk Analysis)** aims to identify potential damage based on estimates of settlement and internal structural vulnerabilities of buildings.

This minimum impact area, defined in the project phase as an area with settlement greater than 10 mm, is a trapezium described by the following points (see also the Figures below).

In tunnels, on the surface, two points are selected on either side of the tunnel axis, each at a maximum horizontal distance equal to three times the tunnel's maximum horizontal width from the axis, and underground, two points are selected at a depth of 5 m from the lower level of the tunnel's outer face, from which external tangents are drawn.

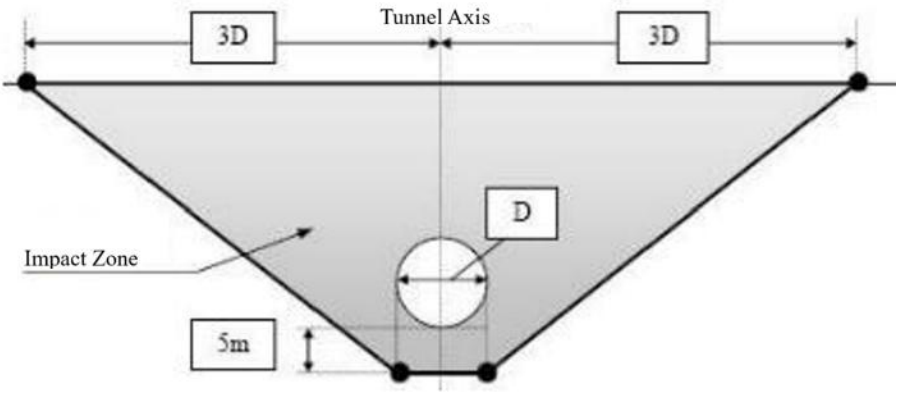


Figure 5.21 : Minimum impact area for tunnels

For cut-and-cover structures, this is represented by a shape formed by connecting points on the surface located at a distance of 1.5 times the excavation depth (d) from the excavation edges, with points at the bottom of the excavation located 5 m from the deepest outer points of the excavation.

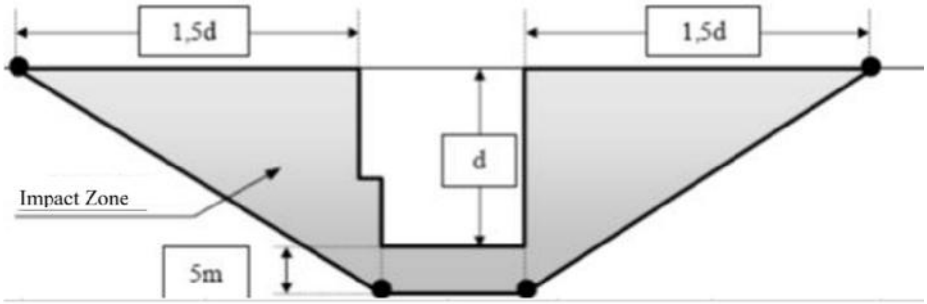


Figure 5.22 : Minimum influence zone for cut-and-cover structures

During the preliminary assessment phase, research into the effects of deformations caused by excavation work on a tunnel or station is generally based on experimental methods. These will be verified by reference to technical documents that are widely accepted in professional literature and based on engineering experience. Such methods enable the determination of the dimensions and shape of the subsidence basin caused by the excavation. The building risk assessment is therefore carried out by following the steps below:

1. Stage

Identification of settlements caused by excavation works carried out in undeveloped areas. The effect of building foundations on the settlement pattern is not taken into account. Any structure where the estimated settlement is less than 10 mm and the estimated rotation caused by differential settlement is less than 1/500 (this value depends on the building typology) does not

require further assessment. All other structures within the impact area will be subject to Stage 2 assessments.

2. Stage

Structures subject to settlement caused by excavated tunnels (or other excavations) are assessed individually, as in the previous stage analysis, using a limiting tensile stress approach. In this assessment method, tensile stresses within the ground are taken into account, and a simplified, idealised model of the building is utilised. Use will be made of tests and proven references from the literature.

3. Stage

All structures classified as grade 3 or higher in Burland's(*) damage classification table will be subject to further investigation during the second-stage assessment process.

This method involves a numerical modelling-based soil-structure interaction analysis that takes into account the stiffness (rigidity) of the foundations.

(*) Burland, Standing, Mair (2004) Advances in geotechnical engineering. Soil performance and building response associated with tunnel construction – Skempton Conference.

Burland, Taylor, Mair (1996) Geotechnical aspects of underground construction on soft ground.

Burland, Standing, Jardine (2001) Building response in tunnel construction. Case studies from the construction of the Jubilee Tunnel extension in London.

5.12.3.2. Stage 1: Settlement Calculation Method – Theoretical Formula

As previously noted, calculation methods are based on experimental observations validated by experienced contractors in the field and the technical literature. This method enables the determination of the shape of the settlement area caused by excavation in locations where no existing structures are present (undeveloped areas or undeveloped land conditions). The settlement curve resulting from excavation works on a circular tunnel follows a Gaussian distribution. Numerous studies conducted in the past regarding different geotechnical conditions (Attewell and Taylor, 1984(1); O'Reilly and New, 1982(2); New and O'Reilly, 1991) confirm the effectiveness of this approach.

The method is based on the definition of the percentage volume loss caused by excavation and the assumption that the shape of the settlement curve depends on the 'k' parameter.

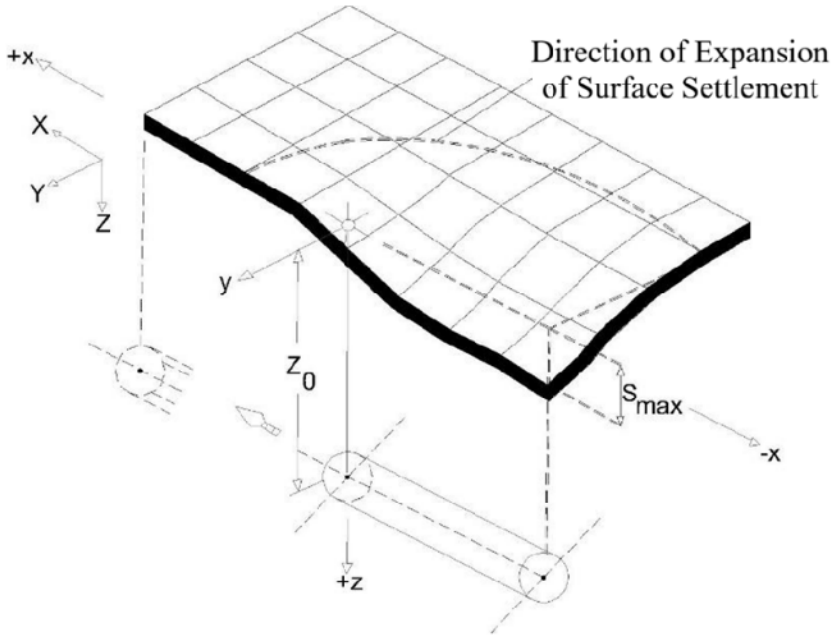


Figure 5.23 : Shape of the settlement area caused by tunnel excavation (under undeveloped ground conditions)

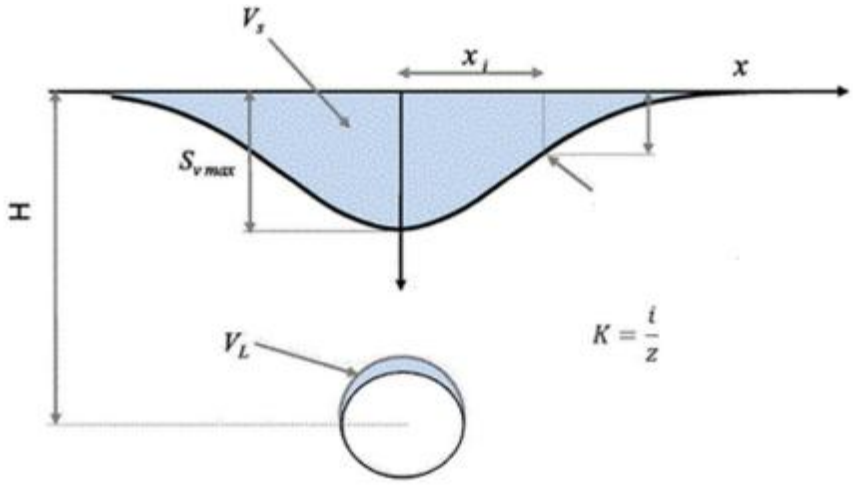


Figure 5.24 : Typical Gaussian settlement curve (Transverse profile of the settlement trough)

In particular, during the excavation of twin tunnels located close to one another, with a cover thickness <2D and in weak ground conditions, there may be an overlap in the interaction zones between the excavation of the tunnel excavated first (the leading tunnel) and the tunnel excavated later (the trailing tunnel). In such cases, the trailing tunnel will be excavated in the ground disturbed by the leading tunnel. It should be noted that, as a result of similar situations, the material parameter (k) value—which determines the form of the settlement curve and represents the properties of the excavation material—may increase for the second tunnel (Mahmutoğlu, 2011). During the construction phase, it is important to limit interference within the tunnel influence zones in such sections.

(1) Attewell, P. B. and Taylor, R. K. 1984. Ground movements and their effects on structures. Chapman and Hall.
(2) O'Reilly, M.P., and Yeni, B.M., 1982. Overhead settlement in tunnels in the UK – magnitude and prediction. Published in: Tunnelling'82, London. Istanbul Metropolitan Municipality, pp. 173–181.
(3) Mahmutoğlu, Y., 2011. Surface subsidence induced by twin subway tunnelling in soft ground conditions in Istanbul. Bulletin of Engineering Geology and the Environment, vol. 70, pp. 115–131.

5.12.3.3. Stage 2: Identification of Potential Damage to Buildings

To identify potential damage to an existing structure, most authors suggest acceptable values for the general deformation parameters of a building to account for different settlements within the foundation.

At the same time, a comprehensive bibliography on the subject is available. Based on the documents in this bibliography, and drawing on experimental observations and experience, it is possible to define a set of damage classes using the characteristic parameters employed to determine the resulting deformations.

It should be emphasised that settlement itself does not cause damage to structures, and other parameters relating to the interpretation of settlement data will also be defined.

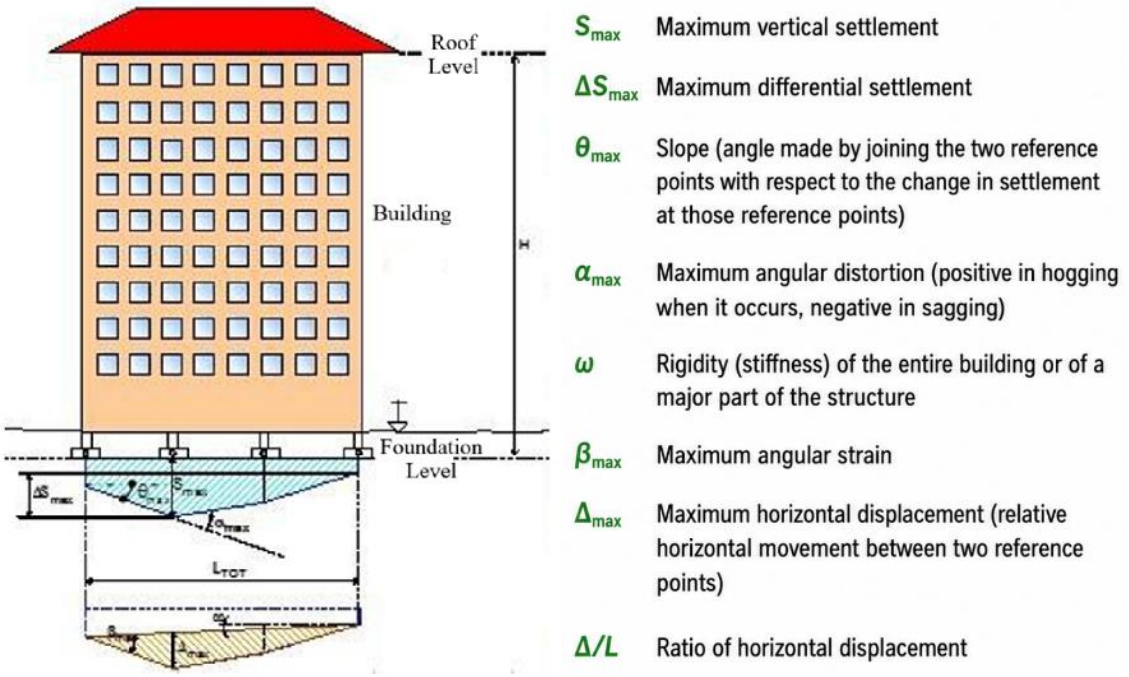


Figure 5.25 : The most important factors relating to settlement-induced damage in buildings

Deformation limit values are provided in the studies by Burland (1997) and Boscardin and Cording (1989) (*), and these studies define a different damage classification method based on existing cracks in the structure.

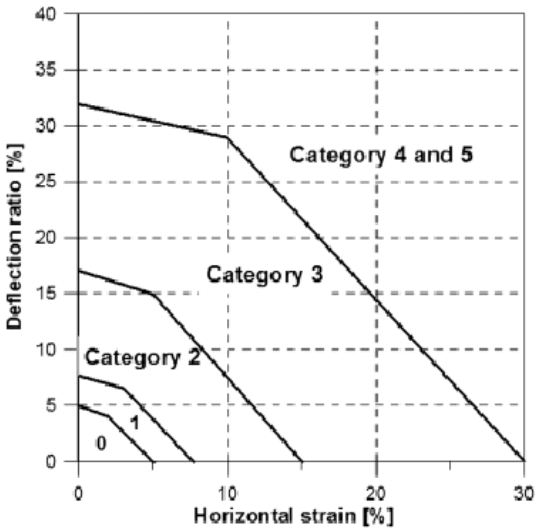


Figure 5.26 : Damage table for building risk analyses (Boscardin and Cording, 1989)

(*) FHWA Reference: “Building Response to Excavation-Induced Settlement”, J. of Geotech Eng., 1989

Table 5.5 : Classification used for damage assessment in buildings

Damage Classification	Description of Damage Grade	Description of typical damage and likely repair methods for a typical masonry building	Smax [mm]	β lim [%]	Maximum tensile strain ε lim [%]	Approximate crack width [mm]
0	None	Capillary cracks.			Less than 0.05	
1	Very slight	Fine cracks that can be easily repaired during routine maintenance. Likely, a minor, isolated crack within the building. Cracks in the external brickwork that are only visible upon close inspection.	10	0.002	0.05–0.075	0.1–1
2	Minor	Cracks that can be easily filled. Repairs are likely to be required. A few minor cracks may have formed inside the building. Visible cracks on the external facade: may require some touch-ups to ensure weather resistance. Doors and windows may be slightly difficult to open and close.	50	0.005	0.075–0.15	1–5

Damage Classification	Description of Damage Grade	Description of typical damage and likely repair methods for a typical masonry building	Smax [mm]	β lim [%]	Maximum tensile strain ε lim [%]	Approximate crack width [mm]
3	Moderate	Cracks require repair. Recurring cracks can be sealed with a suitable coating. Recessed jointing of external brickwork and, possibly, a small amount of material replacement may be required. Doors and windows are difficult to open and close. Utility services may be disrupted. Waterproofing is frequently compromised.	75	0.02	0.15–0.3	5–15 or more than 3 cracks
4	Severe	Requires extensive repair involving the complete demolition and reconstruction of wall sections, particularly those above doors and windows. Window and door frames are warped. Visible slopes form in the flooring. Visible warping or swelling is observed in the walls, and there is some loss of load-bearing capacity in the load-bearing beams. Utility services are disrupted.	75	0.02	Greater than 0.3	15–25, but also depends on the number of cracks
5	Very severe	Requires major repairs involving partial or complete reconstruction. Beams lose their load-bearing capacity, walls become excessively warped and require shoring. Windows break as a result of impact. There is a risk of instability.				Generally greater than 25, but also depends on the number of cracks

5.12.3.4. Stage 3: Focus on Critical Conditions

Buildings identified in the second-stage assessment as having a damage class of 3 or higher (Figure 5.38) will be subjected to a more comprehensive soil-structure interaction analysis using a numerical modelling method, taking into account the stiffness of the foundations. The results of the numerical models can be presented in the form of a building damage classification, as shown in the table below.

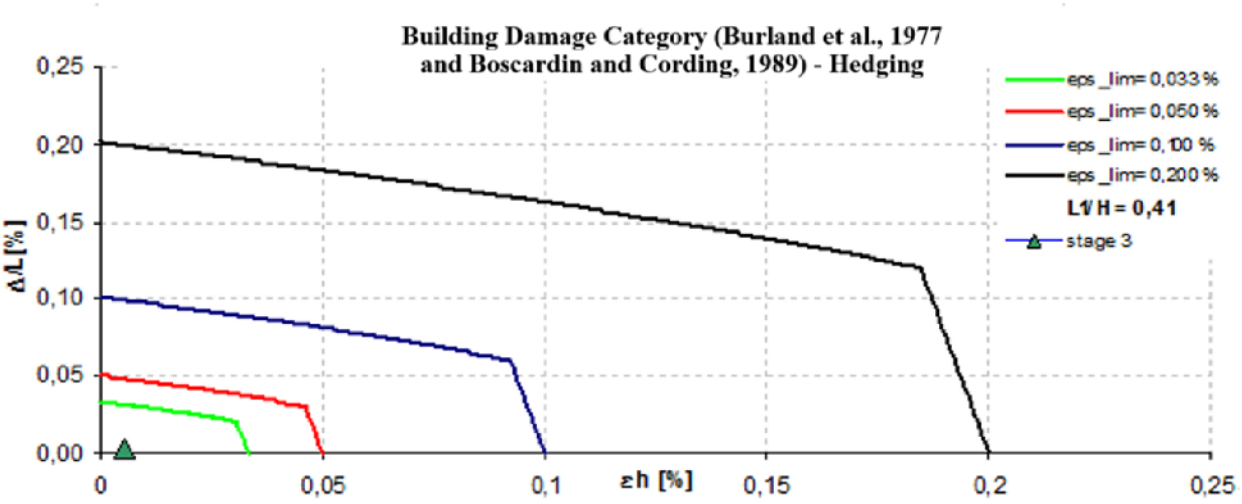


Figure 5.27 : Risk analysis for new buildings

5.12.3.5. Ground Improvement – Alternative Technical Solutions

Generally, buildings not affected by tunnelling activities will be classified into risk class 2 or below. Otherwise, countermeasures may be implemented. These measures are typically applied to improve the strength and deformability of the ground near the buildings. Three possible consolidation models that may be applied if the damage class exceeds 2 as a result of the "building risk assessment" are presented below:

- **Tunnel roof reinforcement**: This can be achieved by creating an arch over the tunnel roof and partially the side walls using a series of vertical jet-grout injections. This measure helps to reduce volume loss during excavation and consequently minimises the impact on the surface.

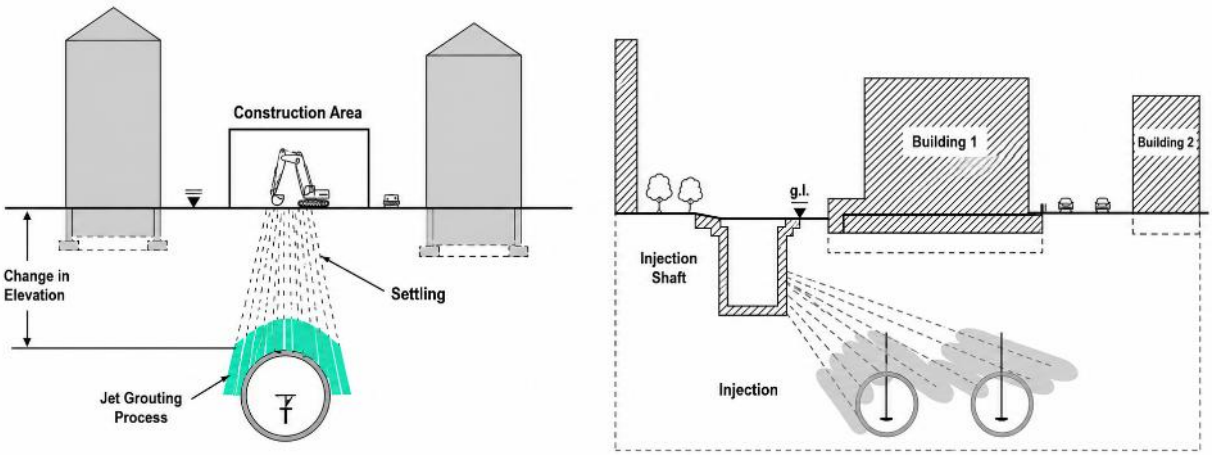


Figure 5.28 : Ground improvement at tunnel level from above (left) and from a lateral shaft (right)

- **Lateral column improvement:** injections of varying widths are made perpendicular to the surface between the tunnel and the building foundations.

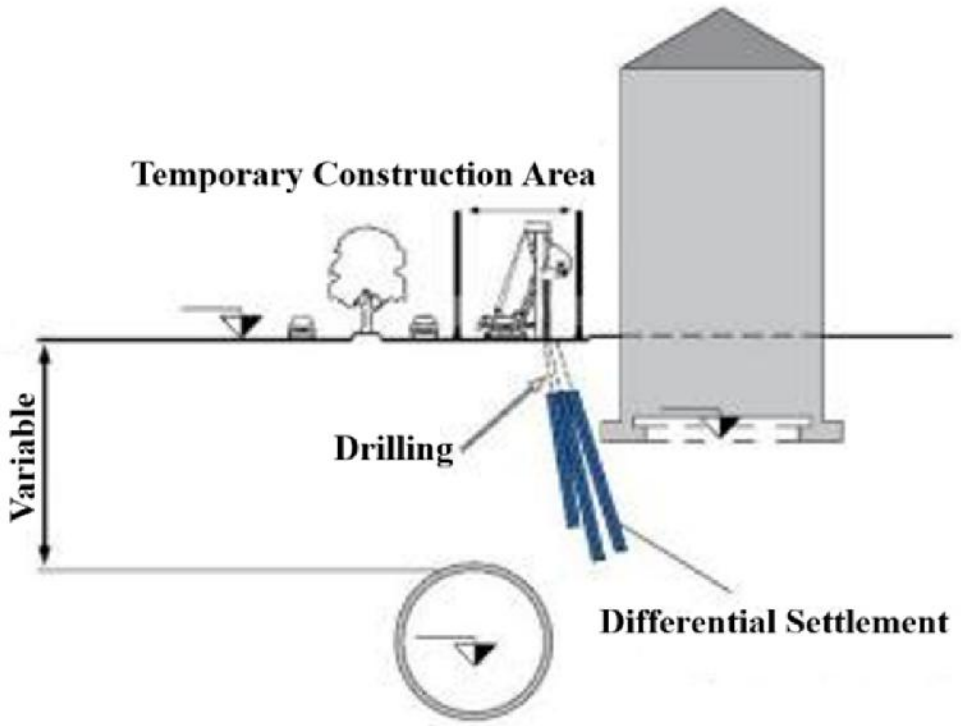
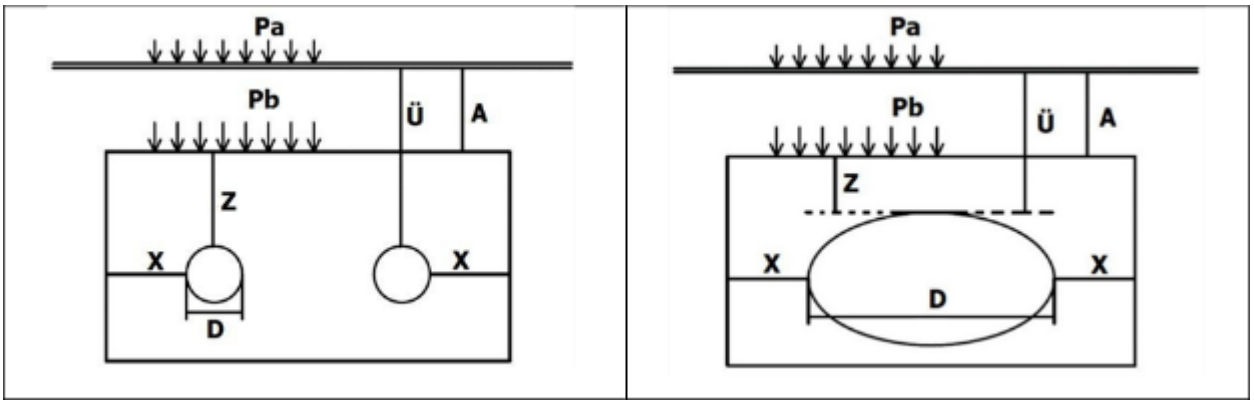


Figure 5.29 : Ground improvement near the tunnel

5.12.3.6. Restrictions on New Development on the Railway Line Surface Following Tunnel Construction

Once tunnel construction is complete, new development on the railway line surface must be restricted. A detailed analysis will be carried out for these restriction conditions. Information regarding soil stress limits and the areas through which the line passes, as shown in the example diagrams below, must be communicated to the relevant authorities (municipalities, etc.).

Table 5.6 : Summary table showing ground stresses



Z and Ü	X	Maximum permissible ground stress Pa and Pb
Ü ≤ D Z = D	X = D + Ü/2	Pa = 50 kN/m²
Ü = D – 20 m Z = D + Ü/2	X = 1.5D + (Ü – D)/4	Pa = 50 (1 + Ü – D/20 – D) Pb = Pa + Ax² 20 kN/m²
Ü ≥ 20 m Z = D + Ü/2	X = 1.5D + 5	Pa = 100 kN/m² Pb = Pa + Ax20 kN/m²

5.12.4. Design Criteria for Excavation and Support Structures

5.12.4.1. Selection of the Excavation Support System

Within the scope of excavation support system analyses, the decision regarding the excavation support system will be made by taking into account, as a priority, the excavation geometry, ground/rock conditions of the project area, groundwater conditions, settlement density around the excavation, expropriation boundaries, existing infrastructure and roads, and displaced infrastructure and road projects, etc. Potential excavation support systems include: free-slope excavation, excavation supported by rock bolts and/or ground anchors, spaced or intersecting cantilever piles, diaphragm walls supported by pre-stressed ground anchors and/or struts/internal support elements (steel pipes, reinforced concrete beams, etc.), diaphragm walls constructed using the top-down method, and anchored curtain walls, etc. The lengths of the elements constituting the excavation support system will be determined by taking into account the groundwater and soil/rock conditions at the project site, and in such a way as to minimise water seepage from the excavation base during construction and ensure the stability of the excavation base.

5.12.4.2. Excavation Support System Analyses

Free-slope excavation analyses and analyses of excavations supported by rock bolts and/or ground nails will be performed using internationally recognised software capable of limit equilibrium analysis.

The minimum safety factors required for temporary free-slope stability analyses shall be determined in accordance with FHWA or the European Standard Eurocode 7.

Excavation analyses supported by rock bolts and/or ground anchors shall be carried out in accordance with the FHWA 0-IF-03-017 specification, and the safety factors recommended in the relevant specification for temporary structures shall be used. Sectional verification analyses of surface lining elements (sprayed concrete, steel mesh, etc.) shall be carried out in accordance with the conditions specified in TS 500.

Diaphragm walls supported by cantilevers, pre-stressed ground anchors and/or internal support elements (steel pipes, reinforced concrete beams, etc.), diaphragm walls to be constructed using the top-down method, and analyses of anchored curtain walls shall be performed using internationally recognised software capable of finite element/finite difference analysis.

Taking into account whether the support system is permeable or impermeable, appropriate groundwater conditions will be defined in the finite element analyses. In the analyses, in addition to the detailed excavation geometry, surrounding buildings will also be defined by applying surcharge loads appropriate to their storeys. All excavation and construction stages will be modelled in the analyses; displacements and section forces (moment, shear force, axial force) occurring in the soil and support system elements at each stage, as well as the envelopes of these values covering all stages, will be reported. The analysis results will demonstrate that the expected vertical displacements and angular rotations in adjacent structures are below the limits specified in FHWA or European Standard 7.

The safety factors to be used for pre-stressed ground anchors (for root friction and cable breakage), the calculation of the anchor root length and the minimum free lengths of the anchors shall be determined in accordance with the BS 8081 and FHWA-IF-99-015 specifications. The prestressing load to be used in prestressed ground anchors shall be determined at approximately 70–85% of the safe anchor capacity, taking into account the surrounding development. Earthquake loads shall not be considered in the temporary shoring design.

5.12.4.3. Section Verifications

As a result of the analyses, the calculated section forces (moment, shear force, axial force) in reinforced concrete elements (piles, diaphragm walls, etc.) will be increased in accordance with the load combinations specified in TS 500, and the reinforced concrete design will be carried out in accordance with the methods specified in TS 500.

In the section verification analyses of steel members (steel pipe supports, etc.), in accordance with safe stress design criteria, the maximum section forces determined for these members in the analysis models will be used without applying any load factor, and the section verification analyses will be carried out in accordance with the conditions of the Regulation on the Design, Calculation and Construction Principles of Steel Structures.

5.12.4.4. Ground and Wall Movement Analyses

Ground and wall movement limits shall be assessed in terms of the safety of both the excavation support system and the surrounding structures. For this purpose, FHWA and/or the European Standard EuroCode 7 may be used.

Detailed explanations regarding displacement limits are provided in Section 5.11 ‘Wall and Ground Movements’ of FHWA-IF-99-015.

5.12.5. Monitoring Design Criteria

5.12.5.1. General

This section sets out the criteria required for project drawings and technical specifications, etc., to be prepared for the monitoring of projects.

These criteria will be based on technical documents published by the FHWA and ITA. Furthermore, when monitoring existing buildings, the criteria provided in the Building Risk Analysis (BRA) section of this guide will also be taken into account.

The displacement limits for excavation and support systems will be assessed in terms of the safety of both the excavation support system and the surrounding structures. For this purpose, FHWA and/or the European Standard EuroCode 7 may be used.

Detailed explanations regarding displacement limits are provided in Section 5.11 'Wall and Ground Movements' of FHWA-IF-99-015. Detailed monitoring design drawings and technical specifications shall be prepared by the project designers in accordance with this technical document or equivalent internationally recognised supplementary documents such as.

Information regarding the minimum requirements to be adhered to in the monitoring of projects is provided below:

- A building instrumentation plan covering the types of equipment to be used, their locations, and the frequency of readings/measurements.
- Preparation of an instrumentation report including device types, locations, intended uses, limit values, calibration and reading/measurement criteria.
- Interpretation, analysis and monitoring of the equipment in relation to neighbouring buildings, structures, tunnels, shafts and open excavations.

The monitoring system will serve two purposes:

- Monitoring during the execution of the works; this will be supplemented by an analysis of actual conditions in relation to project assumptions, and necessary measures will be taken should a situation arise that threatens the safety of the worksite and surrounding structures,
- Monitoring during the operational phase is carried out to control the performance and behaviour of the works carried out.

The design will be carried out using suitable equipment capable of sustaining monitoring activities throughout the operational phase to achieve these two objectives. Consequently, the selected monitoring equipment will meet the following criteria:

- High spatial resolution (spatial distribution) and temporal resolution (reading frequency).

- High accuracy and reliability
- Sufficient data storage capacity
- Rapid installation and short reading/measurement time.
- Ease of maintenance.

Measuring instruments should be installed to monitor ground and structural deformations caused by deep excavations and bored tunnels. The installed equipment must monitor the following parameters:

- Movements of the ground and structures
- Stress and strain within the ground and structures.
- Water pressure and level

Table 5.7 : Classification regarding the assessment of damage within buildings

ELEMENT BEING MONITORED	KEY PARAMETER	POSSIBLE INSTRUMENTS
Ground	Deformation behind retaining structures	Inclinometers **(IN)** Inclinometers and incremental extensometers **(EIN)**
	Surface settlements	Topographic levelling **(CPL)**
	Surface displacement	Topographic 3D checks **(CTC)**
	Piezometric levels	Piezometers **(PZ)**
	Water flow into excavations and underground structures	Flow meter **(FM)**
	Ground acceleration	Accelerograph **(AC)**
Open/Close structures (station, entrances, ramps and shafts)	Stresses acting on struts	Strain gauges embedded in concrete/sprayed concrete **(SM)** or welded to steel structural members **(SG)**. Strain gauge, sm
	Deformation in diaphragm or pile walls	Inclinometer **(IN)** Topographic 3D monitoring **(CTC)** Optical reflector for convergence **(CT)**
	Load on temporary anchors	Load cell for anchorage **(LC)**
	Deformation in temporary and permanent structures	Strain gauges embedded in concrete/sprayed concrete **(SM)** or welded to steel structural members **(SG)**
	Cracks detected in buildings	Electrical or mechanical crack gauges **(FS)**
	Settlements in a building	Building settlement bolt **(BS)** and topographical levelling **(CPL)**

Existing Structures	The rotation or inclination of a building's external facade	Two-axis inclinometer **(CL)**
	Displacement of the upper floors of the building	Optical targets for topographic 3D checks (CTC)
	Accelerations, vibrations and low-frequency noise	Accelograph **(AC)** and vibration and overpressure monitors **(VNM)**
NATM tunnel and shaft structures	Ground deformation around the tunnel	Multi-point bar extensometer **(MPBX)**
	Deformation of temporary support	Optical reflector for convergence **(CT)**
	Pressures acting at the soil-temporary support interface	Pressure cell **(PC)**
	Temporary support deformation of the final coating	Strain gauge embedded in concrete/sprayed concrete **(SM)** or welded to steel structural members **(SG)**

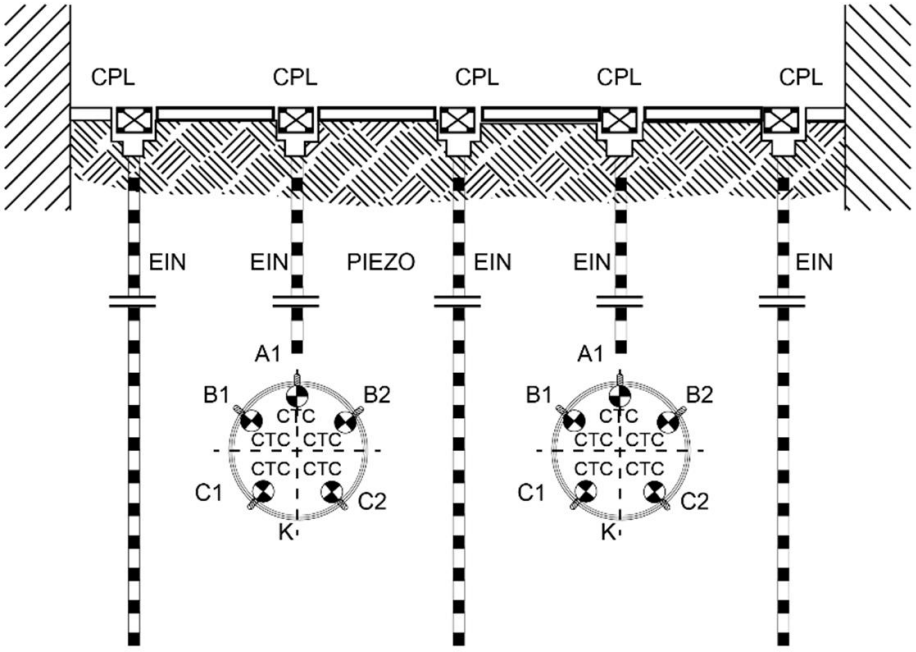


Figure 5.30 : Standard monitoring station for urban rail tunnels

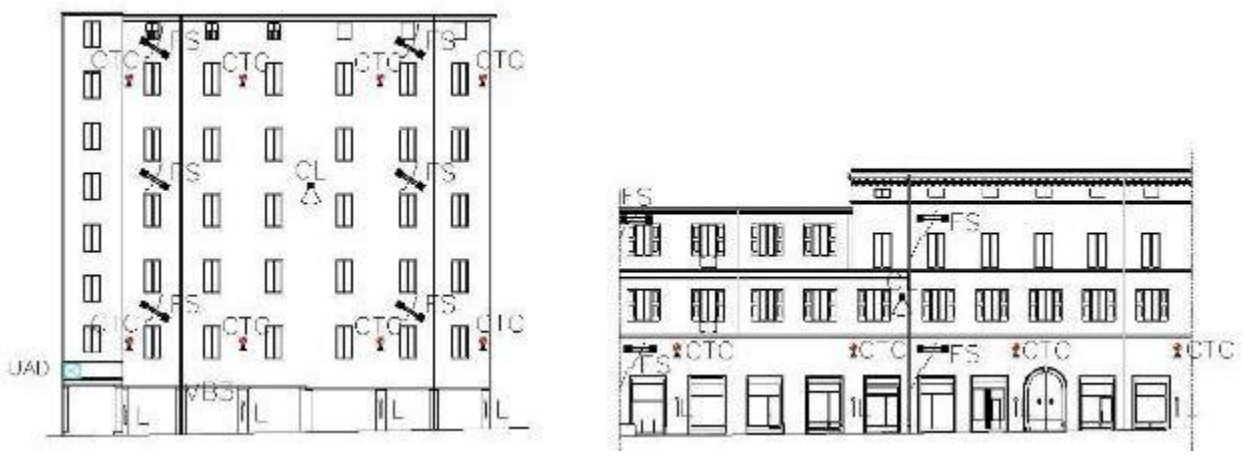


Figure 5.31 : Example of a monitoring system installed within buildings

The monitoring points to be installed on the building must be planned to include at least three of the building's corner points. In other words, they must be selected in such a way as to enable the determination of displacements in the X, Y and Z directions. Readings in a single direction in the horizontal plane are insufficient for determining displacements in all directions.

5.12.5.2. Monitoring Criteria

One of the key aspects of the monitoring process is the tracking of horizontal and vertical movements throughout the ongoing construction period. Monitoring instruments should be designed to provide information both during and after the construction process.

Control sections shall, where possible, be positioned perpendicular to the tunnel alignment.

All surface monitoring points and building inspection prisms shall be directed towards fixed benchmarks located outside the tunnel's influence zone; in other words, they shall be situated at a reasonable distance from the expected settlement zone and sufficiently far from the tunnel alignment to avoid the tunnel's influence.

The design of fixed benchmarks for Surface Monitoring Points (SMPs) shall be the same as that for the Surface Monitoring Points themselves. The same criteria shall apply to fixed benchmarks for building monitoring points.

Measurements at Surface Monitoring Points (SMP) will be carried out using a levelling instrument; the location of the relevant benchmarks determines the length and accuracy of the levelling circuits. This will be taken into account in the design of the levelling circuits to ensure appropriate accuracy.

In addition to the general principles for monitoring along the route, there may also be critical infrastructure—such as pressurised gas, electricity or water transmission lines—which requires intensive monitoring and protection where necessary. A specific inspection plan for this infrastructure will be defined in the final monitoring design in the form of special interaction zones, and infrastructure monitoring points will be linked to instruments such as an electrolytic horizontal level, a vibrating-wire deformation measurement device, or even an electrical resistance-wire deformation measurement device.

Some key monitoring sections will be positioned along the route for structural and settlement analyses. Segments equipped with vibrating-wire pressure cells, vibrating-wire strain gauges and convergence gauges will be installed in the tunnel lining. One reason for installing these sections is to demonstrate how the opening of the second tunnel interacts with the first tunnel, imposing additional loads on the first tunnel's lining, and to validate the design assumptions.

Deformations occurring in the ground, buildings and infrastructure during tunnel excavation must be measured. In addition, changes in the groundwater level, changes in water pressure and vibrations generated by the EPB during drilling must also be measured.

To monitor changes in the groundwater level caused by the tunnel boring and lining itself, a specific number of piezometers will be installed between the two tunnel lines, each equipped with at least one sensor at the axis depth. Provided that the ground strata are generally defined as low-permeability, these sensors will be vibrating-wire type. If deemed necessary during implementation, vertical-tube piezometers may also be installed. The tip of the vertical-tube piezometers must be placed in sandy soil and non-clayey soil. The depth and spacing of piezometers shall be determined based on geological conditions, hydrogeological regime, excavation depth, tunnel invert level, groundwater table elevation, permeability of soil and rock strata, anticipated drawdown effects, adjacent structures and environmental sensitivity. The final arrangement shall be subject to approval by the Engineer.

Piezometer monitoring shall commence prior to the start of construction in order to establish baseline groundwater conditions. Baseline readings shall be obtained at least once per week for a minimum period of four weeks. During construction, the monitoring frequency shall be adjusted according to the construction activity, groundwater response and risk classification of the monitored area. Daily or continuous automatic monitoring shall be provided during dewatering, deep excavation, tunnelling in water-bearing strata, or where trigger levels are approached or exceeded. Monitoring frequency shall not be reduced without the approval of the Engineer.

Trigger levels for piezometer monitoring shall be established by the Designer and approved by the Engineer prior to commencement of construction activities.

The trigger level system shall include; Alert Level, Action Level and Alarm Level. The trigger values shall be defined relative to baseline groundwater levels, predicted groundwater drawdown,

pore pressure limits, allowable uplift pressure, settlement criteria, environmental impact thresholds.

All instruments to be used within the monitoring programme—including the topographic theodolite (total station), levelling instrument, inclinometer, extensometer, tilt sensors and their corresponding readout units—must be calibrated by an official laboratory approved by the contractor. In addition, calibration requirements must be met for components such as vibrating-wire reading units used for vibration recording and three-axis seismographs.

At the end of the equipment removal process, certain components to be used may be adjusted for subsequent use in other projects. However, these components will be installed before work commences and will remain in the same position until the removal method is implemented.

5.12.5.3. Definition of Inspection Levels

Within the framework of common practice, the following levels will be defined:

a) Attention Level:

- Definition: This will be set at a certain safety level below the project's highest or lowest value (whichever is appropriate). For example, this value could be within a range such as 50%–75%.
- **Possible countermeasures**: underground monitoring equipment, increasing the frequency of measurements in the ground and buildings. Preparing a plan to prevent reaching the Warning Level, etc.

b) Warning Level

- Definition: The value will be set at a level below the project's highest or lowest value (whichever is appropriate) by a specified safety margin. For example, this value could be within a range such as 75%–90%.
- **Possible countermeasures**: The comprehensive verification of structural integrity and the implementation of countermeasures, such as ground improvement or measures to avoid risks arising in structures such as buildings, tunnels, stations, shafts, etc., will be carefully assessed.

An example table of key parameters, threshold values and cost-effective measures to be followed is provided below (Table 5.8).

Table 5.8 : Summary table of key parameters, threshold values and countermeasures (example)

KEY PARAMETERS	CONTROLS	EQUIPMENT AND MEASUREMENTS	THRESHOLDS		POSSIBLE PRECAUTIONS
			Alert Level (Permitted Level)	Warning Level (Permitted Level)	
STRUCTURES UNDER CONSTRUCTION	Tunnel Closure	Closure measurements			Improvement of excavation procedures. Ground improvement Additional consolidation measures Construction suspension (also in the event of exceedi the YSS) Structural reinforcement (in the event of exceeding the YSS) Increasing the number of anchors
	Stresses within temporary (shoring) and permanent structures	Strain gauges Radial pressure cells			
	Stress within temporary anchors of pile walls	Load Cells	These levels will be determined based on the analysis results provided by the Project Designers and the technical documents of organisations such as the FHWA and ITA. These levels will be specified in the projects and the technical specifications to be prepared.		
SOIL AROUND STRUCTURES UNDER CONSTRUCTION	Surface settlement	Surface levelling Incremental extension-slope scales			
	YSS	Piezometers			
BUILDING SAFETY	Surface settlements	Monitoring of building settlements Optical targets			Special measures for the protection of buildings Potential disruptions during excavation Improvement of excavation procedures
	Settlement of buildings	Crack gauges			
TBM excavation	Weight of excavated material	Stability on bedrock			Adjustment of the volume of excavated material Drilling holes from the surface to locate voids and filling them with low-pressure grout
	Pressure at the face	Sensors on the face			Verification by adjusting the rotation speed of the screw conveyor Bentonite injection on the face
	Grout injection volume	Data logger			Additional secondary injections from the tunnel Filling and grouting to fill voids from the surface
	Grout injection pressure	Data logger			Pressure regulation

5.12.5.4. Tunnel lining monitoring

The first stage involves the tunnel lining itself. In a reinforced ring, there are five key parameters to be monitored: earth pressure, internal deformation of the segments (axial and deflection), and global ring deformation (ovality, relative displacement).

Soil pressure: This is measured using vibrating wire pressure cells, which are embedded within the concrete forming the segment and levelled with the segment's outer surface.

Internal segment deformations caused by ground stress can be measured using deformation measurement devices. In thick or thin concrete segments, these devices can be mounted in pairs to calculate axial deformation (the average of the two values) and deflection (the difference between the two values).

The load cells and deformation measurement devices will be installed at the segment manufacturing plant prior to concrete pouring and secured to the steel reinforcement within the formwork. This process takes approximately one hour for each device installed. To avoid halting production at the manufacturing plant, part of the work can be carried out by aligning and positioning the instruments in the final moments before concrete pouring, prior to the steel reinforcement being placed in the formwork. This work takes place over only a few square metres near the formwork.

This can be monitored using topographical instruments such as ovality inclinometers – which are rarely used in TBM tunnels, as the presence of a backup system makes it difficult to find cross-sections where measurements can be taken – or by taking theodolite (total station) readings on prisms fixed to the inner surface of the lining. Whilst the passage of the backup system obstructs the reading, any accepted solution will measure ovalisation over the medium and long term. The relative displacement between rings or segments, which is normally observed as gross displacement, can be easily measured using a specially designed tape measure. The scope of this initial monitoring phase is to control the lining behaviour and, in addition, to verify the actual loads on the lining against the structural design assumptions. The information required for the technical specifications to be prepared for the construction phase will be based on the information provided in this section.

a) Reinforced Sections Excavated Using the Conventional Method

In tunnel sections excavated using the conventional method, convergence measurements are taken across cross-sections. The shape of these cross-sections depends on the type of section and the condition and class of the soil/rock. Similarly, geological conditions will be taken into account for the spacing between measurement cross-sections. Figure 5.43 shows two example convergence configurations depending on the section type and excavation stages.

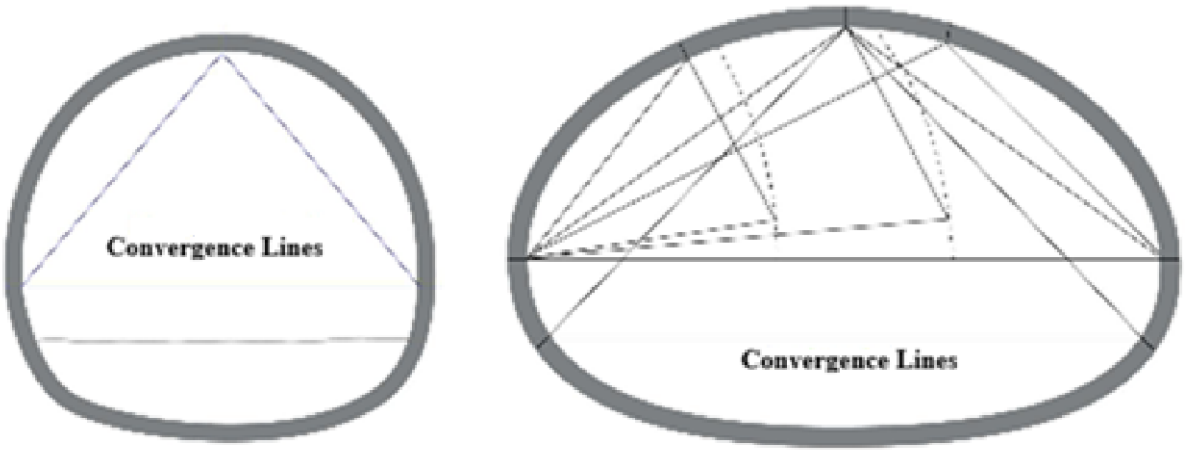


Figure 5.32 : Examples of convergence sections depending on excavation type, cross-section geometry and size

b) Reinforced Ring

Internal deformation in the segments is determined using vibrating wire strain gauges mounted on the segments. These are installed in pairs, with one element welded to the outer surface of the reinforcement bars and the other to the inner surface. Each pair is positioned to centre the segment. In this way, axial and bending deformations can be determined for each segment. The reinforced ring will be installed as shown in the figure to maximise the bending deformation to be measured in the key segment.

In addition, to measure the deformations caused by the TBM thrust pistons, a vibrating-wire strain gauge will be mounted on each segment of the reinforced ring. All these elements will be mounted together with the reinforcement within the lining to prevent excessive deformation of the sensors.

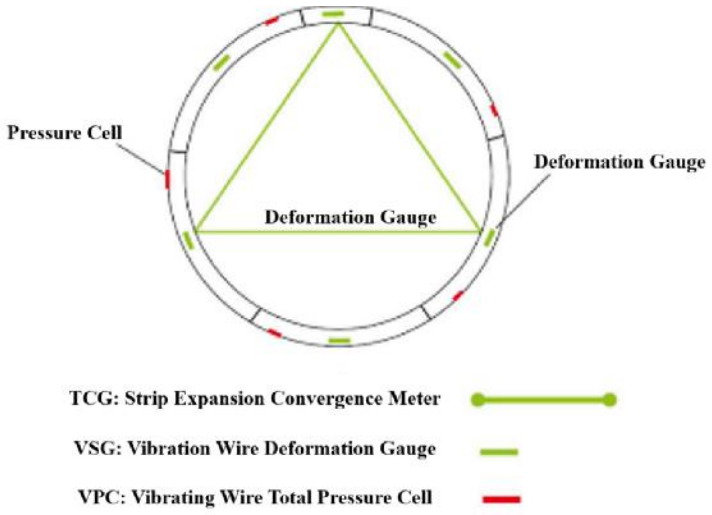


Figure 5.33 : Equipped ring diagram

5.12.5.5. Monitoring Programme

Readings from measurement devices installed in the field, other than seismographs, will be collected. Vibration measurements will be read, collected and analysed by an independent firm. The criteria given in this section apply to all underground and surface instruments, as well as building and infrastructure measurement points.

Initial Reading

The baseline reading shall be taken after the installation of the individual monitoring instrument and, for borehole instruments, once the grout has set, the temperature has stabilised and the groundwater level has returned to its original level, in the presence of the relevant parties, such as the Contractor, the Consultant, etc.

The reading shall be determined by taking the average of three separate, complete readings taken at different times over three consecutive days. During these readings, the operator shall record the date and time of the reading, the assistants present, atmospheric conditions, rainfall events in the preceding weeks, and other observations that may affect the measurements, such as nearby infrastructure.

There will be some exceptions to the general method for basic readings taken using piezometers and pressure cells.

Piezometer readings will be taken at the moment the vertical pipes or sensors are installed. The reading will be determined by taking the average of three separate readings taken one, two and three weeks after installation. However, the data read at the moment of installation will be noted as an additional value in the data list.

Regarding pressure cells and deformation measurement devices in the segments: it will be borne in mind that the greatest fluctuation in the readings of these instruments will occur during installation and within a few hours after installation as the grout sets. For this reason, the readings from the installed vibrating wire devices will be taken as quickly as possible to obtain useful stress readings whilst they are being mounted and as the TBM advances. Accordingly, the baseline readings for these devices consist of a single reading immediately following installation and subsequent readings based on that initial reading.

Reading Frequency During Normal Operation

During tunnel excavation, the reading frequency of the installed instruments varies depending on the distance from the tunnel face in NATM excavation and the distance from the TBM cutting disc in TBM excavation.

The area affected by the excavation varies along the tunnel, depending on ground conditions and tunnel depth, as detailed in the site investigation reports. In principle, given the limited on-site experience, it can be assumed that the area affected by the excavation will extend at least 50 metres ahead of and 100 metres behind the excavation activity (tunnel face/TBM), and will be determined independently for twin-tube tunnels. If the measuring instruments do not reach stabilisation at the end of the affected area, daily readings may be extended until stabilisation is achieved. A reasonable stabilisation value for displacement instruments is specified as 1 mm/week.

5.12.6. Monitoring of TBM Parameters

The parameters to be monitored include location, direction, kilometre, elevation, horizontal angles, gradient, advance rate and piston, as well as advanced orientation parameters of the Tunnel Boring Machine. Similarly, TBM parameters such as the thrust force applied to the shield, the torque applied to the cutter head, excavation energy consumption, and pressure on the excavation face will be obtained via the TBM's integrated software and kept under control.

During the monitoring design phase, operational values and thresholds for key TBM parameters, such as soil thrust or grout pressure, will be determined based on the ground conditions and tunnel geometry.

5.12.6.1. Settlement Levels

Permissible settlement limits will be specified in the Technical Specifications to be prepared, and it will be stated that these will be continuously monitored. Permissible limits may be determined in accordance with criteria provided by organisations such as the FHWA and ITA. Furthermore, the information provided in the Risk Analysis of Structures section of this guide will be taken into account.

For all tunnel excavation methods, geotechnical finite element/difference software will be used to calculate deformations and loads in the tunnel supports. This software, specifically developed for geotechnical simulation, will be capable of simulating both ground reactions and the behaviour of segmental structures. At specific points, such as connection tunnel junctions, it may be necessary to use 3D models suitable for 3D geometry.

In accordance with the expected reference levels, advanced levels such as the Investigation Level or Warning Level will be considered in the design, alongside the design levels and safety limits specified in the Technical Specifications.

5.12.7. Cable Ducts and Pedestrian Walkways

Cable ducts and walkways shall be provided on at least one side of the track bed along the main line. Cable ducts shall be compartmentalised and self-draining for communication and control purposes, and may be used to support pedestrian walkways.

The lower interior sections of station platforms shall be arranged as cable ducts provided they are of sufficient width and height to allow staff access and to permit crawling.

Cable ducts and walkways shall be designed to facilitate maintenance of switches, switch machines, cable joints and other track-mounted equipment.

Walkways in track structures shall be of a standard that ensures safe and comfortable passage for passengers and staff, with a minimum width of 90 cm in the centre and 70 cm at the sides. The clear height of the safety zone above the walkway shall be a minimum of 200 cm. Walkways may be constructed of concrete or steel mesh and may be combined with cable ducts. Passenger handrails shall be provided at a distance from the track lines.

Covers placed over cable ducts shall be designed so that they do not fall into the duct due to vibration.

In double-track sections, the walkway may be constructed between the two tracks. Where obstacles such as columns or signalling equipment are present on the walkway, provided they are within a short distance, a clear passage of at least 45 cm in width shall be provided.

5.12.8. Other Structures

These include Emergency Exit Structures and Emergency Ventilation Structures located throughout the tunnels, Drainage Pump Stations in tunnel and cut-and-cover sections, and Tension Power Transformer Structures installed along the route as required.

In addition, these include roadway & pedestrian overpasses and underpasses, culverts and ecological overpasses or underpasses as continuation of motorway ecological bridges if required located along the alignment. For these type of structures, General Directorate of Highways (KGM) loadings and specifications shall be used.

5.12.8.1. Emergency Exit Structures

The dimensioning of emergency exit structures will be based on the passenger load of a single train stranded in the tunnel during peak hours. Under no circumstances shall the width of the staircase be less than 1.20 metres.

5.12.8.2. Ventilation Structures

Where additional emergency ventilation fans are required in tunnels as per emergency ventilation calculations, ventilation shafts shall be installed.

In the design, the following aspects shall be taken into account: the openings of the ventilation shafts must be above the maximum water level; a grating capable of bearing the required load must be installed at the top of the shafts; and any water entering through the ventilation shaft

must be channelled into the drainage system before reaching the tunnel alignment. The requirements for these structures shall be met in accordance with the conditions set out in Section8.3 .

5.12.8.3. Traction Power Transformer Substations

Traction Power Substations shall be provided as defined in Section 7 Electrical Systems.

5.12.8.4. Drainage Pump Stations

A drainage pumping station shall be designed at all low points where the system's drainage outlet level is at or below the lowest level of the existing drainage line to which the system is connected. A sufficient number of pumps shall be installed to ensure that the pumping capacity does not fall below a certain level (for details, see Section 8.6).

5.13. ELECTRIFICATION SYSTEMS

5.13.1. Purpose & Scope

This document has been prepared to explain the general design principles/criteria for overhead contact systems (OCS) within the scope of electrification systems in the railway sector.

OCS installations shall be constructed in accordance with national and international standards, suitable for the operating speed (which shall be the test speed plus 10%), and designed to be commissioned in a safe and secure manner.

The design life of the entire system to be installed (excluding the contact wire) shall be at least 40 years.

5.13.2. Terminology

The OCS shall be designed to provide reliable current collection at all approved operating speeds up to 160 km/h +%10 and under all specified environmental conditions.

The Contractor shall generally design the catenary system in accordance with the TS EN 50119.

The OCS shall be designed specifically for design speed current collection stability and shall provide reliable operation throughout the full operational speed range and environmental envelope.

The system shall consist of the following components:

- Foundations
- Masts

- Portals
- Messenger wire
- Contact wire
- Droppers
- Registration assemblies
- Cantilevers and supports
- Anchors and tensioning devices
- Feeders, jumpers and connectors
- Section insulators / overlap arrangements
- Return current and bonding interfaces

5.13.3. Design Criteria for Catenary Systems

The Contractor shalll be use the following system specific data in OCS design:

- Design speed 160 km/h
- Control speed 176 km/h
- Nominal contact wire height 5.30 m
- Min. contact wire height (without speed restrictions) 5.00 m
- Min. system height (open track and stations) 1.60 m
- Min. system height (tunnels/under bridges) 1.10 m
- Min. distance between messenger and contact wire 0.50 m
- Nominal stagger 0.20 m
- Pantograph half width 0.80 m
- Nominal distance between track C/L and mast C/L 3.25 m
- Min. distance between track C/L and mast C/L 2.80 m

5.13.4. Catenary System Design Criteria

Contractor shall design the catenary installations in accordance with the standard of TS EN 50119.

Voltage levels of the catenary system shall be designed in accordance with TS EN 50163. Insulator distances shall be compatible with the static and dynamic conditions in line with TS EN 50119.

To serve as the basis for an assessment of how the conductor system is affected by the pantograph's movement and the relationship between the pantograph and the catenary line (Dynamic Behaviour), in accordance with TS EN 50317; a computer simulation will be carried out, the type of catenary system will be determined using a dynamic simulation programme, and the system will be designed in accordance with the project speed. This dynamic simulation study will be submitted to the Authority for approval.

The dynamic simulation criteria will comply with the TS EN 50367 standard. The results obtained from the software used for dynamic simulation will be verified in accordance with the TS EN 50318 standard. The software used for dynamic simulation will be certified in accordance with the relevant international standards.

Half-width of pantograph is 800 mm and its total length is 1600 mm within the framework of the design purposes of the catenary installation. During design of the catenary installation, it shall be ensured that carbon strips of pantograph are eroded properly, and pantograph is not damaged or there is no cavitation or erosion on some parts of pantograph at the speed of 160 km/h.

The system height shall not be less than 1.60m on open lines and stations and not less than 1.10m at tunnels and under bridges with low height. Vertical distance between contact wire axis and porter wire axis shall be minimum 500mm at any point of the catenary line contacting with pantograph. Stagger shall be nominal ± 200mm.

The contact wire height shall be nominal 5.30m. In mandatory circumstances, the contract wire height may vary, and it shall be 5.00m at least. However, the safety spans stipulated in the standards shall be observed in a way not to result in any speed limitation below 160 km/h.

The catenary system shall be designed in a way to ensure that electrical units and locomotives will be able to receive the traction current through the contact wire up to the speed of 160 km/h+10% without experiencing any troubles.

The wind speed to be used for the wind load that is influential on the catenary system shall be chosen according to the regional meteorological data obtained from the General Directorate of Meteorology, and submitted to the approval of Engineer and the design shall comply with this wind speed. Ice load zones shall be identified using "Turkey Ice Load Map"

All overhead catenary system components intended for installation in open-air sections — including but not limited to droppers, clamps, registration arms, tensioning devices, and insulators — shall be specifically rated and tested for cold climate performance. Component specifications shall demonstrate suitability for operation under the combined effects of accumulated ice loads, sub-zero temperatures, and thermal cycling across the full design temperature range. The Contractor shall provide manufacturers' cold climate certification or equivalent third-party test evidence for all such components as part of the design submission.

As an anti-icing design measure, insulators used in the overhead catenary system shall be provided with hydrophobic or anti-icing surface coatings or shall be of a profile geometry demonstrated to minimise ice accretion under the climatic conditions of the project area. Droppers shall be designed and specified to remain functional under ice-loaded conditions without loss of contact geometry or electrical continuity. The Contractor shall assess the risk of ice bridging across insulator strings and provide engineered solutions — which may include booster insulators, shed-profile insulators, or RTV silicone coatings — as part of the detailed design of the catenary system.

Contractor shall define the following by taking into account the ambient temperature in accordance with the relevant standards:

- The mechanical tension forces of the running wire and carrier wire,
- Thermogram of the automatic tensioning device,
- Adjustment table of mid-point anchor conductor of porter,
- Thermal tensile forces and deflections of the return and supply conductors,
- Span and stagger calculations for overlap spans and insulated overlaps at open lines, tunnels and viaducts,
- Displacement amounts of the cantilever equipment depending on temperature changes and other similar details

Contractor shall calculate, according to the load combinations given in the standard of TS EN 50119, the loads that are influential on the catenary masts, and choose the mast type based on the maximum load.

The soil resistance shall be measured, and calculations shall be made accordingly before the project of the mast and anchorage foundations of the catenary installation is designed.

All necessary static calculations relevant with mast and anchorage foundations shall be made and their basic dimensions shall be decided according to these calculations.

If the catenary equipment is fixed on tunnel walls, bridges and viaducts, marquees, walls and overpasses, all design calculations necessary for fixing points shall be submitted to the approval of Engineer before assembly.

The return current and earthing system of the catenary line shall be designed as a whole considering their impacts on the signalling system.

The conductors, cables and busbars to be used in the system shall be calculated and selected in terms of current carrying capacity, voltage drop and short circuit.

Contractor shall calculate the system impedance (Z, R and X) of the catenary line.

All danger and warning signs requested by the related standards to be applied for safety and protection purposes shall be designed in a way to have the dimensions and properties in accordance with the standards.

Each catenary installation shall be assessed in terms of its location and surrounding ground conditions and Contractor shall take the necessary measures to prevent intruders from climbing onto the structures on the site.

Separate masts shall be used during the design process as much as possible.

The span between the track axis and the mast axis shall be nominal 3.25m and minimum 2.8m. However, this span may be between 3.60m and 4.80m for passenger platforms, loading ramps etc. In mandatory conditions, by obtaining the permit of Engineer, it will be possible to erect the masts in a way that they will not be within the construction gauge.

The information which may be required for track superstructure, signalling, telecommunication and support systems during the desing process shall be received from the Technical Specifications for Track Superstructure, Signalling, Telecommunication and Support Systems.

5.13.5. OCS Type Selection

In scope of the catenary system design the Contractor shall select a catenary arrangement suitable for operation, taking into account:

a) train speed;
b) dynamic current collection requirements;
c) route geometry;
d) bridge, tunnel and station constraints;
e) maintenance strategy;
f) lifecycle cost.
g) TCDD practices on lines with similar speed limits.

The selected catenary type shall be validated by dynamic performance criteria for 160 km/h operation.

5.13.5.1. Open line – Standart Cantilever Assembly

For open line sections, a high-performance flexible catenary system suitable for 160 km/h operation shall be used unless otherwise approved.

The dimensions of various types of cantilevers will be determined according to the calculations to be made for the catenary suspended by the cantilever assembly. The insulators used in the cantilever assembly will be of the same type.

Double Cantilever Set: A double cantilever set refers to two standard cantilever sets mounted on a single traverse on the pole. This cantilevers set will be installed in equipment and sectioning areas, as well as at track switch points.

The distance between the two cantilever sets depends on the catenary expansion at minimum and maximum temperatures. To prevent unwanted contact between the two cantilever sets at extreme temperatures, the first cantilever set will be installed close to the automatic tensioning device. In the event of a rise in temperature, both cantilever sets will move in opposite directions relative to each other. When calculating the distance between the two cantilever sets, the clearance distance in the sectioning and neutral zones will also be taken into account.

5.13.5.2. Stations / special trackwork:

Geometry-specific design speed arrangements shall be provided.

The catenary system at Stations shall be in accordance with catenary system in tunnels. Where there is no space for a raised anchor, the anchor will be designed to bear the entire load on the anchor pole. All anchors installed at stations will be high anchors.

5.13.5.3. Tunnels / restricted clearance areas:

The system must be implemented in accordance with the minimum contact wire height.

The electrical clearance for the catenary in tunnels shall be at least 320 mm, and at least 500 mm in overpasses.

Electrical protection (earthing) shall be provided for all structures required for the installation of the cantilever-hanger assembly in the tunnel.

For cases of critical clearance constraints, the Contractor shall assess the suitability of ROCS and shall design such system where necessary.

Other matters relating to the catenary system in tunnels shall comply with the TSI “Safety in Railways Tunnels” EU Commission Decision.

The selected catenary type shall be validated by dynamic performance criteria for 160 km/h operation.

5.13.6. Conductors

5.13.6.1. Contact Wire

- The contact wire shall be copper or copper alloy suitable for design speed service, wear resistance and current carrying capacity.
- Contact wire shall be AC 120 mm2 CuAg0,1 type in accordance with TS EN 50149 Standard. Contact wire shall be domestically manufactured.
- The material constituent of wire shall meet the values specified in Annex B to EN 50149 Standard

5.13.6.2. Messenger Wire

- The messenger wire shall provide adequate mechanical stability under all load cases and shall be sized for the approved design speed catenary arrangement.
- Porter wire shall be 70 mm2 BzII type in accordance with DIN 48201. Porter wire shall domestically be manufactured.

5.13.6.3. Other Conductors and Cables

Stitch wire: 35 mm2 Bz II in compliance with DIN 48201

Dropper: 16 mm2 Bz II in compliance with DIN 43138

Supply Conductor: HAWK 280.84 mm2 Al/St in compliance with EN 50182 and IEC 61089

Return Conductor: OSTRICH 176.9 mm2 Al/St in compliance with EN 50182 and IEC 61089

Connection between Two Catenaries, Two Porter Wires and for Feeder and Sectioners: 120 mm2 stranded copper conductor in compliance with DIN 43138

Connection of Paralleling and Earthing Electrodes: Insulated & galvanised steel conductor with a 10-mm diameter

Earthing Connections: Aluminium wire rod with a 8-mm diameter

Return Conductor/Steel Mast - Rail Connection: 1x50 mm2 NYY copper cable.

Clamps and fittings to be used for conductor connections shall be vibration-resistant and suitable for the dynamic environment of 160 km/h operation.

5.13.7. Mechanical Tensioning

The catenary shall be designed providing automatic tensioning equipment.

The Contractor shall determine:

a) tension values;
b) anchor lengths;
c) tension length limits;
d) compensation travel;
e) behaviour at extreme temperatures.

The system shall maintain acceptable uplift, sag and contact force stability throughout the specified temperature range.

5.13.8. Design Speed Dynamic Performance

The Contractor shall demonstrate by simulation and testing that the OCS provides acceptable performance in terms of:

- mean contact force;
- statistical variation of contact force;
- uplift at supports;
- loss of contact limits;
- wave propagation behaviour;
- registration accuracy under wind load;
- acceptable behaviour at overlaps and turnouts.

5.13.9. Special OCS Areas

Special design solutions shall be developed for:

a) crossovers;
b) turnouts;
c) neutral sections;
d) station throats;
e) bridge transitions;
f) tunnel entrances and exits;
g) depot access and maintenance sidings, where applicable.

Each special area shall be separately analysed and documented.

5.13.10. Overlap Spans, Insulated Overlaps and Neutral Sections

5.13.10.1. Overlap Spans

- Overlap spans are established at the locations where two tensioned catenary sections belonging to the same electrical zone are merged.
- The horizontal distance between catenaries in overlap spans shall be minimum 200mm
- In order to maintain electrical continuity between catenaries at the beginning and end of every tension length, supply wires made of copper conductor with a 120-mm² section shall be installed.

5.13.10.2. Insulated Overlaps

- Insulated overlaps are established at the locations where two electrically-insulated catenary sections are merged.
- The distance between the energised parts of the differently-sectioned catenary systems in the insulated overlap shall be minimum 450mm.
- Two electrical zones shall be separated from one another with the insulators to be installed on the porter and contact wires of both catenaries. The distance between the intermediate insulator and the nearest bracket tube shall be 2m under average temperature. The line sections between intermediate insulators and anchorage masts shall be connected to the catenary of the other section to avoid potential difference.

5.13.10.3. Neutral Sections

- Neutral sections are the catenary sections that prevent short circuit by bridging the two electrical sections supplied on different phases during the transition of the electric railway vehicle pantograph.
- Neutral sections shall be established in front of substations and at an equal distance to the centre of two substations approximately.

- In case one of the substations is deactivated, the neutral sections shall be equipped with the devices that will allow for merging of the catenary sections on both sides, energising of the non-energised catenary section if necessary, paralleling of the lines, protection of the catenary line if required and monitoring of the energy status of the tracks.

5.13.11. Rigid Overhead Catenary System (ROCS)

5.13.11.1. General

Where used, ROCS shall be designed for the applicable operational speed and route-specific clearance limitations.

The ROCS shall be designed as a complete system including conductor profile, contact wire, support brackets, expansion devices, anchors, joints, electrical continuity arrangements and all associated fittings.

5.13.11.2. Tunnel and Restricted Clearance Application

ROCS shall be used where flexible OCS is not suitable due to:

- limited structural clearances;
- tunnel geometry;
- high maintenance constraints;
- fire strategy requirements;
- interface limitations with ventilation or tunnel lining systems.

5.13.11.3. Design Requirements

ROCS shall be designed for the speed applicable to the relevant section and shall include:

- aluminium conductor profile or equivalent approved assembly;
- compatible contact wire;
- expansion devices;
- support brackets and anchors;
- continuity bonding;
- maintainability and replacement strategy;
- fire and smoke performance compatible with tunnel requirements.

5.13.12. Support Structures and Foundations

5.13.12.1. Structures

All masts, portals, booms, cantilevers, headspans and related structural elements shall be designed for all applicable load cases, including:
a) permanent loads;
b) conductor tension loads;
c) wind loads;
d) accidental conductor break loads;
e) maintenance loads;
f) seismic loads;
g) fatigue effects, where relevant.

The contractor shall calculate the loads acting on the catenary masts in accordance with the load combinations specified in the TS EN 50119 standard and shall select the masts type based on the maximum load.

5.13.12.2. Foundations

Foundations shall be designed in accordance with the approved geotechnical parameters and shall satisfy requirements for strength, settlement, stability and durability.

Foundation design shall also consider drainage, accessibility, track settlement effects and adjacent structure constraints.

5.13.12.3. Civil Interface Requirements

Following interfaces will be taken into consideration during the design:

a) bridge expansion movements;
b) tunnel fixing inserts and tolerances;
c) drainage conflicts;
d) walkway and maintenance access;
e) emergency egress routes;
f) platform canopies and architectural clearances.

5.13.13. Return Current, Earthing And Bonding

5.13.13.1. General

A complete return current, earthing and bonding system shall be designed in compliance with TS EN 50122 to ensure:

a) personnel safety;
b) protection of equipment;
c) fault current return integrity;
d) compatibility with signalling and telecom systems;

The general purpose of earthing and earthing connection is to protect life safety, devices and equipment and operate the line reliably. Earthing system has the following effects:

a) Short circuit protection
b) Protection of the exposed electrical parts against indirect contact
c) Rail potential
d) Overvoltage protection for devices
e) Electromagnetic compatibility
f) Protection by transmitting dangerous voltage rises, which emerge under undesired conditions, to the ground
g) Effects on the signalling system.

Return current circuit, earthing and connection system shall ensure the following:

a) It shall ensure that the short circuits are safely perceived and disconnected, and the fault current is high enough and the short circuit impedance is low enough to open the related circuit breaker.
b) All earthing and connection precautions shall provide protection against electric shocks and unpermitted contact voltages. The earthing resistances of the masts, foundations and, if required, additional earthing layouts shall be as low as possible. All equipotential line connections of devices and hardware shall be provided.
c) The devices, insulated underground high voltage cables and wiring shall be protected against overvoltage reliably.
d) The earthing and connection of the catenary system shall be designed in a way to prevent voltage induction on telecommunication and signalling cables and minimise the electromagnetic interference in other systems.
e) The system shall be produced taking into account the signalling system in order to ensure safe operation of the signalling system.

One of the protection precautions given in the Earthing Regulation shall be applied on posts for 230 VAC side, and hence the necessary precautions for life safety shall be taken.

5.13.13.2. Earthıng Connectıons

In the earthing system, earthing stations shall be established in order to provide additional safety by increasing the system trans-conductance to the ground. The earthing station shall consist of minimum 3 electrodes. No chemical liquid or dust shall be used to provide the necessary resistance.

The return conductors in the earthing system shall be connected at the intervals which will take into account the requirements of the signal system, in line with the catenary earthing system design requirements.

The return conductors in the earthing system shall be connected to rail at the intervals determined by the catenary earthing system design requirements and taking into account the requirements of the signal system.

5.13.13.3. Protection Earthing of Open Line Structures

Supports and iron components on the supports shall be connected to the return conductor with aluminium wire rods. The components on the steel masts shall not be connected separately to the return conductor. The railings at the viaducts shall be longitudinal and continuous. In case of non-continuous viaduct railings, continuity shall be ensured by connection through two-sections of hot-dip galvanised steel conductor with a diameter of 10mm. Viaduct structure earthing and railings shall be connected to the return conductor through the catenary masts at the intervals no more than 150m. Connection to the return conductor shall be made in the same way with assembly of the earthing station conductor. For the connections, cable lugs shall be used.

Hot-dip galvanised steel plates with dimensions of 4000x50x5mm shall be installed on the beams at both sides of the overpasses in a way that they will be placed on the lower corners of the beams at the shortest distance possible over every track. The distance between the wall plugs used for fixing to the beam shall not exceed 1m. The elements used for fixing shall have the structure to prevent the plate from falling onto the line. The connections between each plate on the same side of the overpass, between the plates and return conductor and between the plates and protection panel (anti-vandalism) shall be made with hot-dip galvanised steel conductor with a diameter of 10mm. The number of the conductors shall be selected in a way to ensure resistance to the short circuit current. The connection of conductors to the plates and protection panel shall be made with cable lug. Claws shall be used for connections to return conductor.

5.13.13.4. Tunnel Protection Earthing

Supports and iron components and anchorages on the supports shall be connected to one another with aluminium wire rods with a 8-mm diameter and connected to the return conductor with a hot-dip galvanised steel conductor with a 10-mm diameter. The conductors shall be fixed to the tunnel wall at intervals no more than 0.5m. Connection to the fixed parts shall be provided with cable lug. The elements used for fixing shall have the strength and resistance to prevent the cable from falling onto the line.

Earthing of the equipment of two slab tracks shall be ensured by merging them longitudinally for the same track and merging the longitudinal connections of both tracks with one another and the busbars mounted on the side wall of the tunnel and the hot-dip galvanised steel conductor with a 10-mm diameter at every 150m. Afterwards, connection shall be made from busbars to both

return conductors. At the same point, the return conductors shall also be interconnected. The conductor shall be run through the section between two slab tracks and the section between the tracks and cable conduit inside a HDPE pipe. For connections to busbar, cable lugs shall be used. For the connections from busbar to return conductor, conductor shall be fixed to the tunnel wall at intervals no more than 0.5m. The elements used for fixing shall have the strength and resistance to prevent the cable from falling onto the line.

The metallic installation throughout the tunnel shall be connected to the busbar on the tunnel wall at 150m intervals with hot-dip galvanised steel conductor with a 10-mm diameter. For connection, cable lug shall be used.

1x50mm2 NYY cables shall be used for the connection of the busbars at the joints of the structural segments throughout the tunnel. For connection to the busbars, cable lug shall be used.

5.13.13.5. Earthing of the Structures not connected to the Catenary Line System

All metal structures, surrounding walls, railings etc. within the catenary site shall be connected to the return conductor with a hot-dip galvanised steel conductor with a 10-mm diameter in accordance with TS EN 50122-1 Standard.

5.13.13.6. Earthing of Buildings

Foundation earthing shall be performed in accordance with the Regulation on Earthing of Electrical Installations. An equipotential busbar shall be established for the earthing line, and the foundation earthing and earthing lines shall be connected to this equipotential busbar. The minimum conductor cross-sections shall be calculated according to the Regulation on Earthing of Electrical Installations and shall not be less than the minimum cross-sections given in the Regulation. Minimum one earthing electrode shall be placed on each corner of the building and shall bear the same characteristics with the ones mentioned in the part for the earthing station.

5.13.13.7. Tunnel Earthing System

The system is based on the principle that the catenary power is cut in case of any failure inside the tunnel and the line is earthed. Thus, such an earthing system enables the emergency teams to respond to the scene in a faster and safer way.

The system shall be applied at the tunnels indicated the supply plan.

The disconnectors and voltage transformers to be used for earthing shall be mounted before the inlet portal and after outlet portal of the tunnel.

The control and signal panel of the system shall be available at the inlet and outlet portals as well as emergency exits, if any, of the tunnel. All panels shall be interconnected via a local network

established inside the tunnel, and they shall be connected to the general communication network over the panel which is available on just one side of the tunnel.

The communication devices to be used for connecting to the general communication network shall be compatible with the requirements of the Technical Specifications for Signalling, Telecommunication and Support Systems.

The network established between the control units shall be ring and redundant, and fiber cable shall be used as communication medium.

The system shall also check continuity of cable connections in order to determine whether earthing has been ensured properly on the catenary line.

The cable section to be used for earthing connections shall be determined taking into account the short-circuit current.

The cable section to be selected shall be higher than the minimum section required for thermal and mechanical strength.

Accordingly, the system components are the following:

a) Motor-operated disconnector
b) Voltage transformer
c) Auxiliary service transformer
d) Control and signal panel for each portal and emergency exit (including all equipment and UPS required for communication)

The system shall primarily be managed by the electrification SCADA centre. Accordingly, in case of an emergency, power of the area that is stated in the notice submitted to SCADA centre is cut by the operator of SCADA centre and then earthing disconnector shall also be switched off by the operator. Whether the catenary line is voltaged or not is checked based on the information received from the voltage transformer.

Only when it is impossible to ensure communication between SCADA and the tunnel earthing system, the earthing system may be locally controlled. When the earthing disconnector cannot be controlled by SCADA centre due to communication failure, the local control button on the control and signal panel that is available at the inlet/outlet portals and emergency exits of the tunnel gives a flashing warning to show that there is no communication. In that case, the system permits local control through this button.

The earthing disconnector shall never be switched off via a remote control or local control when the catenary line is voltaged, and necessary measures shall be taken accordingly.

When it is impossible to receive information from the voltage transformer for any reason, the line shall be considered as powered, and the status of voltage transformer shall constantly be

monitored by the auxiliary fuse contact that is mounted on the voltage transformer. In order to make sure that the line is earthed by the earthing system, continuity of all connections between the catenary line and the earthing point shall be monitored. When a connection cannot be provided, the warning signal which is available on the control and signal panel to indicate that earthing has been ensured properly shall not be activated even if the earthing disconnector is closed.

UPS shall be available to ensure operation of the system for 5 hours in case of a power cut.

The operating status of earthing system shall be indicated with a 3-colour (red, green and yellow) light. If all lights are off, the system is powered. When only red light is on, it indicates that the catenary power is cut and no earthing has been performed yet. A flashing red light indicates that the earthing disconnectors have started changing their positions to ensure earthing. A green light is on when earthing has been performed properly.

If the earthing disconnector is closed but the connection has a problem, the yellow light shall be on. When communication between SCADA and the tunnel earthing system cannot be established, the light button shall give a flashing signal, and in that case, automatic earthing shall be ensured locally via pressing the flashing button on the control and signal panel. This procedure shall be shown on the signal panel in a way that it can be seen by the emergency response staff.

The principle schemes that describe the system, and the detail electrical and mechanical drawings as well as system technical description shall be prepared.

The system design shall take into account "TSI-Safety in Railway Tunnels" and UIC 779-9.

The disconnectors to be used in the tunnel earthing system shall be electrically E2 and mechanically M0 class in accordance with IEC 62271-102 Standard.

5.13.13.8. Catenary Line Protection Earthing Zone

All non-energised metallic parts of the catenary equipment shall be connected to the earthed rail, in other words, non-insulated rails or the other parts of the earthing system. This rule also applies to the metal construction of the concrete masts. Since the conductors will contact the other metal parts following a catenary rupture, all metal construction components that the ruptured conductor will touch shall be connected to the earthing system.

The protection earthing zone is shown as straight lines no. 2 and 3 on the drawing and it applies to straight lines or the curves with a radius above 1000m.

For the curves with radii below 1000m, the boundaries of catenary protection area within the curve shall be increased from 4.0m to 5.0m.

All matters and explanations related to electrical safety, earthing and return current circuit shall comply with TS EN 50122-1 Standard.

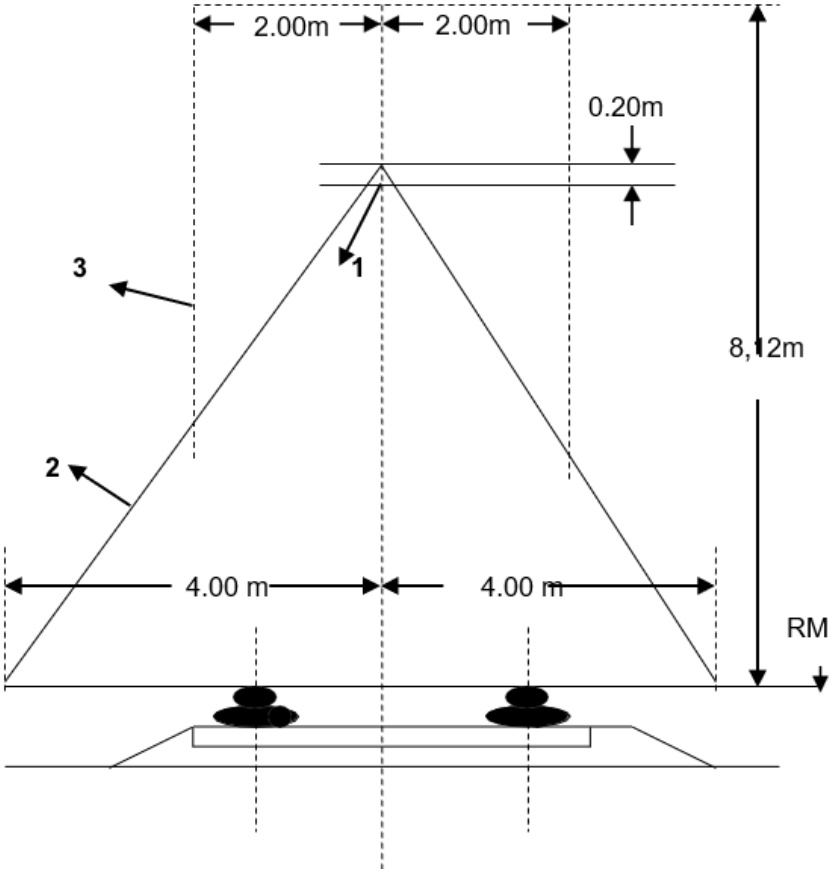


Figure 5.34 : Catenary and Pantogrph Area

Catenary and Pantogrph Area

1. Catenary Wire
2. Catenary Area Boundary
3. Pantograph Area Boundary

5.13.14. Plans, Calculations, Documents and Assembly Drawings

5.13.14.1. General

Design criteria, drawings and documents for the planning and installation of the catenary line, based on the operating speed, shall be provided by the Contractor in the following format.

- Design report
- Catenary system construction methodology
- Feeding plan
- Catenary system route plan (Stakeout plan)
- Layout plan

- Foundation log
- Installation log
- Earthing plan
- System calculations
- Installation principles
- Maintenance documents
- Bracket and hanger hardware and pendulum lengths during the installation phase

5.13.14.2. Design Report

The design report must be prepared in accordance with specifications and standards. It should generally contain information about the project. It must include the climatic and environmental conditions used in the design, the safety factors and clearances to be used, general information on materials, and the types of designs to be applied. It must include the precautions to be taken for components, taking into account the design life of the system, and a list of the standards used in the design.

5.13.14.3. Catenary System Construction Methodology

The methodology must specify the measures to be taken regarding occupational health and safety and environmental protection, quality considerations, the equipment to be used, and the qualifications of personnel, alongside detailed information on the installation of the catenary system in accordance with the specifications, standards, and design report.

5.13.14.4. Power Supply Plan

A supply plan shall include the following details.

- Kilometre locations of transformer stations and neutral zones
- All types of equipment and their locations
- Section area and cut-off points
- Locations of ISs
- List of symbols
- Station entry and exit signals

5.13.14.5. Picketage plan

The following details will be shown on a catenary survey plan.

- Pole number, km
- Number and km of sections in tunnels (The first section from the tunnel entrance and exit portals shall be within a maximum distance of 5 m)
- Spacing between poles along the route
- Section lengths

- Axial deviations (offset)
- Transformer centres, substations, hertz and the kilometres of fixed installations
- Anti-short-circuit locations and anti-short-circuit section lengths
- Locations of return conductor parallel connections, connection points and rail connection points, and earthing stations
- Feeder and return conductor
- Anchors and their types
- Horizontal distances between routes in multi-route systems
- List of special symbols to be included in the layout plan and the symbols used
- Catenary lengths for each station track, including numbered anchor posts.
- Curve radii, clothoids, deviation values, curve start and end kilometres,
- Switch centres and types, line kilometres and the preferred directions for train operations, including the actual location of the track
- Platforms, platform canopies and buildings located near the railway
- Structures (engineering structures) that trains will pass under or over, together with the necessary details such as height, length, line crossing angle and width
- Tunnels and viaducts, with their start and end kilometre points specified
- Electrified lines crossing the railway, including their voltage, purpose and clearance height
- Portals
- Drawings shall be printed in colour, and each conductor will be shown in a separate colour. Catenary sections will be shown in at least two different colours.
- The survey plan will be on a scale of 1:1000 for open lines (Hattı Cari) and 1:500 for station and tunnel sections.
- In special cases, drawings on a scale of 1:100 or 1:200 may be required for tunnel sections. In such cases, approval must be obtained from the Authority.

5.13.14.6. Catenary Layout Plan

A catenary layout plan shall show the following details.

- Pole number and pole type
- Spacing between poles along the route
- Section number and lengths
- Conductor heights
- Axial offsets (deviations)
- System heights
- Locations of insulators, section insulators, catenary crossings, feed connections, equipment and section man areas
- Positions of disconnectors and their blades
- Locations of anti-short-circuit devices and lengths of anti-short-circuit sections
- Feeder and return conductor

- List of special symbols and the symbols used
- Drawings in colour to be printed and each conductor separate colour. Catenary sections shall be shown in at least two different colours.
- The alignment plan shall be drawn to a scale of 1:1000 for open sections (Main Line) and 1:500 for station and tunnel sections.
- In special cases, drawings at a scale of 1:100 or 1:200 may be required for tunnel sections. In such cases, approval from the Authority must be obtained.

5.13.14.7. Foundation Details

Foundation details shall include the following information.

- Pole numbers and kilometre markers
- Spans between poles
- Anchor type and kilometre points
- Soil type
- Foundation type and dimensions
- Core or pile type
- Pole type and height
- Installation
- Distance e (distance between the top of the rail and the top of the foundation)
- Total moment acting on the post
- Overturning moment of the foundation

5.13.14.8. Installation Certificate

The catenary installation record shall be provided to reflect the current status of the poles, foundations, structures and any necessary specific information. It shall include the following details:

- Pole number and kilometre
- Type of foundation for the pole in question
- Pole dimensions (length, pole type, cross-section or side view)
- Distance between the nearest road axis and the pole axis (emplacement)
- e-distance (distance between the top of the rail and the top of the foundation)
- If the foundation is of the bolted type and raised above ground level, the reference number indicating the dimensions, cross-section and length of the bolts.
- The distance between track centres, the distance between the track centres and the route centre, and the viewing direction
- Insulation clearances
- Dimensions of connection parts on the pole relative to the rail level
- Earthing stations, pole rail grounding connection and parallel connections

- Bracket-hoban assembly
- Main design or drawing number for the relevant console-hoban set
- Conductors, conductor heights and system heights
- Curve radius and gradients
- Information regarding consecutive pylons where required
- Base construction

5.13.14.9. Earthing Plan

The earthing plan shall include the earthing connection details of the electrification system. It shall cover the following information in detail.

- Locations, distances (km) and resistance values of earthing stations
- Return conductor parallel connection points and their km coordinates
- Return conductor-rail connection points and their km locations
- Locations and km points of earthing bars in tunnels and on platforms
- Locations and characteristics of impedance bonds where used

5.13.14.10. System Drawings (Assembly Drawings)

System drawings are technical drawings showing the components that make up the system drawn together as a whole, indicating their mounting locations. They will include the following features.

- They shall include all views necessary to fully define the system.
- Dimensions will not be provided unless necessary.
- Each component will be assigned a part or assembly number, and a list specifying the material properties will be included in the system drawings.
- They shall include a text area containing the necessary information.
- It will be in the standard letterhead format used in the project
- The drawings will comply with technical drawing standards.
- Manufacturing drawings for all materials in the system drawings shall be prepared in accordance with technical drawing rules and submitted to the management for approval.
- The direction of load application, as well as the breaking and working loads, shall be indicated in the component drawings.

5.13.15. Standards, and Regulations

In the design, all relevant international standards, national safety legislation and regulations shall be adhered to in order to ensure the safety of personnel working on the construction, operation, maintenance, repair and final acceptance of the system, and to ensure that the catenary system is designed, constructed and tested in accordance with these safety requirements.

The design of catenary systems shall generally be carried out in accordance with the current versions of the standards and regulations listed below.

- TS, TSE, EN
- IEC, IEEE, ANSI
- UIC
- DIN
- ISO, VDE
- TSI Energy Subsystem
- TSI “Safety in Railway Tunnels” EU Commission Decision
- CENELEC
- ISO, VDE
- ASTM
- High-Voltage Installations Regulation
- Regulation on Earthing in Electrical Installations

5.13.15.1. General Standards Relating to the System

Table 5.9 : General Standards Relating to the System

	STANDARD NO	TITLE
1	TS EN 50119	Electrical overhead contact lines
2	TS EN 50122-1	Protective measures relating to electrical safety and earthing
3	TS EN 50122-2	Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 2: Provisions against the effects of stray currents caused by d.c. traction systems
4	TS EN 50124-1	Insulation coordination – Part 1: Basic rules – Insulation clearances and creepage distances for all electrical and electronic equipment
5	TS EN 50124-2	Insulation coordination – Part 2: Overvoltages and associated protection
6	TS EN 50163	Supply voltages for busbar systems
7	TS EN 50317	Verification and rules for the measurement of the dynamic interaction between pantographs and overhead contact lines
8	TS EN 50318	Validation of the simulation between the pantograph and the overhead contact line

9	TS EN 50367	Technical criteria for the interaction between the pantograph and
10	TS EN 50125	Railway applications – Environmental conditions for equipment
11	TS EN 50125-2	Railway applications – Environmental conditions for equipment – Part 2: Fixed electrical installations
12	TS EN 60721-3-3	Classification of environmental conditions – Part 3: Classification of groups of environmental parameters and their severity levels – Section 3: Fixed use in locations protected from atmospheric
13	TS EN 50206-1	Pantographs: Characteristics and tests
14	TSI	Energy Subsystem
15	TSI	TSI “Safety in Railways Tunnels” EU Commission Decision
16	UIC505	Series of standards Railway rolling stock – Rolling stock construction gauge; Effects of the application of the kinematic gauges defined in the 505 series of leaflets on the positioning of structures in relation to the tracks and of the tracks in relation to each other; Common basic conditions for leaflets 505-1 to 505-4; notes on the preparation and provisions of these leaflets
17	UIC600 OR	Electric traction with overhead contact lines
18	UIC606-2 OR	Installation of 25 kV and 50 or 60 Hz overhead contact lines
18	UIC606-2 OR	Installation of 25 kV and 50 or 60 Hz contact lines
19	UIC791 R	Quality assurance of overhead line equipment
20	UIC792 R	Principles for the manufacture and use of portable units for earthing overhead electric traction power lines via the rail
21	UIC 794	Pantograph-Overhead Line Interaction on the European High-Speed Network
22	UIC 799	Characteristics of a.c. overhead contact systems for high-speed lines operating at speeds exceeding 200 km/h

23	UIC 896-2 R	Recommendations for the protection of steel structures against corrosion.
24	TS EN 60060-1	High-voltage test methods – Part 1: General definitions and test rules
25	TS EN 13306	Maintenance - Terms and definitions
26	TS EN 50126-1	Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS)
27	High-Voltage Installations Regulation	
28	Earthing Regulations	
29	TS EN 50121	All standard series Railway applications – Electromagnetic compatibility – Part 1: General Part 2: Emissions from the entire railway system to the external environment Part 3-1: Training and all rolling stock Part 3-2: Train – Equipment Part 4: Emissions and immunity of signalling and telecommunications equipment Part 5: Emission and immunity of fixed power supply installations and equipment

5.13.15.2. Connection Components

Table 5.10 : Connectors Standards

	STANDARD NO	TITLE
1	DIN 43161	Pins for overhead equipment
2	DIN 46235	Cable lugs; for compression connections, cover plate type, for copper conductors
3	DIN 48075-1 DIN 48075-2	Series of standards Parallel groove clamps for aluminium stranded conductors and for steel-reinforced aluminium conductors for overhead power lines; Parallel groove clamps for copper and bronze stranded conductors, for overhead power lines
4	TS 1706	Bolts with hooks and metric threads for high-voltage overhead power lines

5.13.15.3. Cables

Table 5.11 : Cable Standards

	STANDARD NO	HEADING
1	TS EN 60228	Cables – Conductors of insulated cables
2	TS HD 603 S1	Cables – Distribution cables with a rated voltage of 0.6/1 kV
3	TS HD 620 S2	Cables - Extruded-insulated distribution cables - With rated voltages ranging from 3.6/6 (7.2) kV to 20.8/36 (42) kV
4	TS HD 627 S1	Cables - Multi-core and multi-pair - Installed underground and above ground

5.13.15.4. Conductors

Table 5.12 : Conductor Standards

	STANDARD NO	HEADING
1	TS EN 12385-4+A1	Steel wire ropes – Safety Part 4: Stranded ropes for general lifting applications
2	DIN 43136	Span wires for overhead equipment
3	DIN 43137	Electric traction; earthing and return current wires
4	DIN 43138	Flexible cables for overhead equipment and return current
5	DIN 48201	Series of standards Copper stranded conductors; Bronze stranded conductors
6	DIN 48203	Series of standards Copper wires and copper stranded conductors; technical delivery conditions; Wrought copper alloy (Bz) wires and conductors; technical delivery conditions
7	TS EN 50149	Railway applications – Fixed installations – Electrical track laying (electrical track laying) – Copper and copper alloy grooved
8	TS EN 50182	Overhead line conductors – Round-strand concentric-lay braided conductors
9	UIC 870	Technical specification for grooved contact wires
10	IEC 61089	Round wire concentric lay overhead electrical stranded conductors
11	TS 10382 IEC 60840 >> TS IEC 60840	Cables – Power cables and accessories with insulation extruded by drawing, for rated voltages above 30 kV (um=36 kV) up to 150 kV (um=170 kV) – Test methods and characteristics
12	TS 3	Copper conductors – Braided – Used in overhead lines

5.13.15.5. Disconnectors and Drive Mechanisms

Table 5.13 : Standards for Separators and Drive Mechanisms

	STANDARD NO	TITLE
1	TS EN 60947-1	Low-voltage switchgear and controlgear – Part 1: General requirements
2	TS EN 62271-102	High-voltage switchgear and controlgear – Part 102: Alternating current disconnectors and earthing switches

5.13.15.6. General Standards for Materials

Table 5.14 : General Standards for Materials

	STANDARD NO	TITLE
1	TS 3033 EN60529	Degrees of protection provided by enclosures (IP code) (in electrical equipment)

5.13.15.7. Static

Table 5.15 : Static Standards

	STANDARD NO	TITLE
1	TS EN 1992-1-1	Design of concrete structures – Part 1-1: General rules and rules applicable to buildings (Eurocode 2)
2	TS EN 1993-1-1	Design of steel structures - Part 1-1: General rules and rules applicable to buildings (Eurocode 3)
3	TS EN 1997-1	Geotechnical design – Part 1: General rules (Eurocode 7)
4	TS EN 1999-1-1	Design of aluminium structures – Part 1-1: General rules – Rules for buildings

5.13.15.8. Steel and Aluminium Materials

Table 5.16 : Standards for Steel and Aluminium Materials

	STANDARD NO	TITLE

1	TS EN 573-3	Aluminium and aluminium alloys – Chemical composition and shape of formable products – Part 3: Chemical composition
2	TS EN 755	All standard series Aluminium and aluminium alloys – Extruded wire rod, bars, tubes and profiles Section 1: Technical requirements for inspection and delivery Section 2: Mechanical properties Section 3: Round bars, dimensional and shape tolerances Section 4: Square-section bars, dimensional and shape tolerances Section 5: Rectangular bars, dimensional and shape tolerances Section 6: Hexagonal bars, dimensional and shape tolerances Section 7: Seamless pipes, dimensional and shape tolerances Section 8: Pipe fittings, dimensional and shape tolerances Section 9: Profiles, dimensional and shape tolerances
3	DIN 1025-2	Hot-rolled I-beams
4	TS EN 10034	Steel I and H sections – Shape and dimensional tolerances
5	TS EN 10025-1	Hot-rolled structural steels – Part 1: General technical delivery conditions
6	TS EN 10025-2	Hot-rolled structural steels – Part 2: Technical delivery conditions for non-alloy structural steels
7	TS EN ISO 6892-1	Metallic materials – Tensile test – Part 1: Test method at ambient temperature
8	TS EN ISO 148-1	Metallic materials – Charpy impact test – Part 1: Test method (V and U notches)
9	TS EN 10056-1	Structural steels – L-sections and angles – Part 1: Dimensions
10	TS EN 10056-2	Structural steels - L-sections and angles - Part 2: Shape and dimensional tolerances

11	TS EN 10058	Hot-rolled flat steel bars for general purposes – Dimensions, shape and dimensional tolerances
12	TS EN 1090-2	Steel and aluminium structural applications – Part 2: Technical requirements for steel structures
13	TS EN 473	Non-destructive testing – Qualification and certification of non-destructive testing personnel – General rules
14	TS EN ISO 9606-1	Welding qualification tests – Fusion welding – Part 1: Steels
15	TS EN ISO 15614-1	Specification and qualification of welding procedures for metallic materials – Welding procedure test – Part 1: Gas and arc welding of steels, arc welding of nickel and nickel alloys
16	TS EN ISO 898-1	Mechanical properties of fasteners – Manufactured from carbon steel and alloy steel – Part 1: Bolts, screws and studs
17	TS EN ISO 898-2	Mechanical properties of fasteners – Manufactured from carbon steel and alloy steel – Part 2: Nuts with specified strength classes – Standard thread and fine-pitch thread
18	TS EN ISO 5817	Welding – Fusion-welded joints (excluding beam welding) in steel, nickel, titanium and their alloys – Quality levels for defects
19	TS EN 17638	Non-destructive testing of welds – Magnetic particle testing of welds
20	TS EN 571-1	Non-destructive testing – Penetrant testing – Part 1: General rules
21	TS EN 10160	Ultrasonic testing of flat steel products with a thickness of 6 mm or more (reflection method)
22	TS EN ISO 17640	Non-destructive testing of welds – Ultrasonic testing – Techniques, test limits and evaluation
23	TS EN ISO 1461	Hot-dip galvanised coatings on materials made of iron and steel – Properties and test methods

24	ASTM A-239	Standard Practice for Locating the Thinnest Spot in a Zinc (Galvanised) Coating on Iron or Steel Articles
25	ASTM A-90	Standard Test Method for the Weight [Mass] of a Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings
26	IEC 207	Aluminium alloy stranded conductors
27	IEC 209	Steel-reinforced aluminium conductors
28	TS 953 EN 586-1	Aluminium and aluminium alloys – Forgings – Part 1: Technical requirements for inspection and delivery
29	TS 953 EN 586-2	Aluminium and aluminium alloys – Forged components – Part 2: Mechanical properties and other properties

5.14. SIGNALING and TELECOMMUNICATION and SUPPORT SYSTEMS

Design services to be performed by the contractor for Signalling, Telecommunications and Support Systems; the standards and specifications to be used are specified in the Signalling, Telecommunications and Support Systems Specification.

In brief;

- The signalling system and all its components and subsystems, the ERTMS/ETCS Level 1 system, the ERTMS/ETCS Level 2 system and the GSM-R system shall be certified to demonstrate that the systems are reliable and approved.
- The signalling system, all its components and subsystems, the ERTMS/ETCS Level 1 system and the GSM-R system shall have at least one year of operational experience with a reputable railway authority to demonstrate that the systems are reliable and approved.
- All signalling systems, including ERTMS/ETCS Level 1/2 systems, and all telecommunications systems, including GSM-R systems, shall be suitable for train speeds of 200 km/h. At the same time, low-speed trains shall also be able to operate safely and efficiently on this line.
- All conditions and requirements specified in the Technical Specifications for Signalling, Telecommunications and Support Systems for the Istanbul Northern Railway Crossing High- -Speed Train Line shall be met for the entirety of the railway lines shown as signalled in the 'Track-Side Signalling Plan' provided in the tender documents.
- Under the Signalling, Telecommunications and Support Systems Technical Specifications, the systems shall be designed to be integrated and delivered to AYGM in a fully operational state and shall be compatible with the regulations and operations of the national railway network.

Signalling and Telecommunications projects shall be prepared in accordance with the relevant sections and provisions of IRS, CENELEC, IEC and TS. Specific regulations and specification details are listed below. The latest versions of the relevant regulations and specifications must be used.

While FRMCS standards and frequency allocations are not yet finalized, the Contractor shall consider FRMCS-readiness principles during detailed design to the extent reasonably practicable. Such considerations may include scalable telecom architecture, reserve capacity provisions, and migration compatibility assessments, while maintaining GSM-R as the operational baseline system.

Detection system shall be based on track circuits. The detailed track circuit sectioning, block boundaries, failure recovery logic, release procedures and degraded-mode operation rules shall be defined in the signalling design principles, interlocking control tables and operating procedures to be prepared by the Contractor and submitted for approval during detailed design.

Table 5.17 : Signalling standards

Applicable Standards/Regulations/Recommendations	
EN 13232-4	Railway Applications, Track, Switches and Crossings
EN 50121-1 to 5	Railway applications, Electromagnetic compatibility
EN 50122-1	Railway applications, Fixed installations, Protective measures relating to electrical safety and earthing
EN 50124-1 to 2	Railway applications, Insulation coordination
EN 50125-1 to 3	Railway applications, Environmental conditions for equipment
EN 50126	Railway applications, Specification and demonstration of reliability, availability, maintainability and safety (RAMS)
EN 50128	Railway applications, communications, signalling and processing systems Software for railway control and protection systems
EN 50129	Railway applications, Communications, signalling and processing systems, Safety-related electronic systems for signalling
EN 50155	Railway applications, Electronic equipment used on rolling stock
EN 50159-1 to 2	Railway applications, Communications, signalling and processing systems, Safety-related communications (closed or open transmission systems)
EN 50238	Railway applications, Compatibility between rolling stock and train detection systems

Applicable Standards/Regulations/Recommendations	
EN 50261	Railway applications, Mounting of electronic equipment
EN 60529	Degrees of protection provided by enclosures (IP code) (For electrical equipment)
EN 60721-3-4	Classifications of environmental conditions
EN 61373	Railway applications, Rolling stock equipment, Shock and vibration tests
EN 61508-1 to 3	Functional safety of electrical, electronic and programmable electronic safety-related systems
EN 61000-4-2	Electromagnetic Compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test
EN 61000-4-4	Electromagnetic Compatibility (EMC) – Part 4: Testing and measurement techniques – Section 4: Electrical fast transient/burst immunity test – basic EMC publication
EN 61000-4-5	Electromagnetic Compatibility (EMC) – Part 4-5: Testing and measurement techniques – Surge immunity test
EN 61000-6-1	Electromagnetic Compatibility (EMC) – Part 6-1: Generic standards – Immunity for residential, commercial and light-industrial environments
EN 61000-6-2	Electromagnetic Compatibility (EMC) – Part 6-2: Generic standards – Immunity for industrial environments
EN 61000-6-4	Electromagnetic compatibility (EMC) – Part 6-4: Generic standards; Emission standard for industrial environments
DIN 934	Hexagon nuts with metric coarse and fine pitch thread – Product classes A and B
ISO 9241	Ergonomic requirements for office work with Visual Display Terminals
ISO 7250	Basic human body measurements for technological design
IEC 61508	Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems
89/336/EEC	Electromagnetic Compatibility Directive
UIC 734	Adaptation of safety installations to high-speed requirements
UIC 753-1	Technical regulations concerning international railway telephone circuits

Applicable Standards/Regulations/Recommendations	
UIC 753-2	General technical regulations governing the establishment and development of communication capacity over the railway telecommunications network
UIC 753-3	General procedures governing maintenance, operation and performance criteria for the telecommunications network of UIC member railways
Recommendation ITU-T G.703 (2001)	Physical and electrical characteristics of hierarchical digital interfaces
Recommendation ITU-T G.732 (1988)	Characteristics of primary PCM multiplex equipment operating at 2048 kbit/s
UIT-T G.707/Y.1 322 (2000)	Recommendation Network node interface for the synchronous digital hierarchy (SDH) Corrigendum 1 (2001), Corrigendum 2 (2001) and Amendment 1 (2001)
Recommendation ITU-T G.782	Types and general characteristics of synchronous digital hierarchy (SDH) equipment
Recommendation ITU-T G.708	Sub-STM-0 network node interface for the synchronous digital hierarchy (SDH)
ITU-T Recommendation G.704 (1998)	1 544, 6 312, 2 Synchronous frame structures used at primary and secondary hierarchical levels 2 048, 8 448 and 44 736 kbit/s
Recommendation ITU-T G.709	Management aspects of the optical transport network element
ITU-T Recommendation G.781	Synchronisation layer functions
Recommendation ITU-T G.784	Management aspects of the synchronous digital hierarchy (SDH) transport network element
Recommendation ITU-T G.957	Optical interfaces for equipment and systems relating to the synchronous digital hierarchy
Recommendation ITU-T G.958	Digital line systems based on the synchronous digital hierarchy for use on optical fibre cables
ITU-T Recommendation G.783 (2000)	Characteristics of synchronous digital hierarchy (SDH) equipment functional blocks Corrigendum 1 (2001)

Applicable Standards/Regulations/Recommendations	
ITU-T Recommendation G.812	Timing requirements for slave clocks suitable for use as node clocks in synchronisation networks
Recommendation ITU-T I.321 (1991)	B-ISDN protocol reference model and its application
Recommendation ITU-T G803	Architecture of transport networks based on the synchronous digital hierarchy (SDH)
Recommendation ITU-T G811	Timing characteristics of primary reference clocks
ITU-T Recommendation I.610 (1999)	Measurement of round-trip delay using a loopback cell Corrigendum 1 (2000)
ITU-T Recommendation G.813	Timing characteristics of SDH equipment slave clocks (SEC)

6. STATIONS

The most important considerations in the design of urban rail system stations are ensuring the comfortable and safe movement of passengers during normal operating periods and the evacuation of passengers with effective crowd management in emergency situations. In the design and sizing of stations, a balance must be struck between capacity and cost.

A proper station design must incorporate the following features:

- Effective integration with the surrounding area, nearby buildings and other modes of transport
- A spatial design that is simple and easy to understand, facilitating passenger movement within the station and minimising walking distances and times
- Circulation areas free from unnecessary and confusing turns, conflicting pedestrian flows, dead-end routes and bottlenecks
- Safe and comfortable access for passengers from all groups between the platform and the train
- Barrier-free, accessible design for all users
- Clear, easily recognisable passenger areas with short walking routes
- Sufficient escape routes for emergency evacuation measures, prepared for crowding and service disruptions,
- Sufficient technical areas required for track operations
- Controlled/safe access between technical areas and operational rooms and passenger areas
- Spaces that do not hinder camera surveillance for station security

The following national and international standards, regulations, specifications and design criteria shall be adopted in the design of railway station facilities (Table 6.1). Designs shall comply with the most recent editions of regulations and standards.

Table 6.1 : Standards to be followed in rail system station design

STANDARD NO	STANDARD/REGULATION NAME
TS 12127	Urban Roads – Rail Transport Systems – Part 1: Design Rules for Underground Station Facilities
TS 12186	Urban Roads - Rail Transport Systems - Part 2: Design Rules for Above-Ground Station Facilities

STANDARD NO	STANDARD/REGULATION NAME
TS 12525	Fire prevention – Metro and light rail systems – Stations – General
Date: 19 December 2007 Number: 26735	Regulations on the Protection of Buildings Against Fire (+ Regulations Amending the Regulation)
NFPA 130	Standard for Fixed Guideway Transit and Passenger Rail Systems, 2020 Edition
NFPA 101	Life Safety Code
TS EN 13501-1	Building products and building elements, fire classification – Part 1: Classification based on data from fire performance tests
TS 12692	Urban roads – Rail transport systems – Part 13: Design rules for station platform safety edge strips and warning strips
TS 12527	Urban roads – Rail transport systems – Part 14: Station platform seating elements – Design and installation rules
TS 12461	Urban roads – Rail transport systems – Part 8: Station signage – Design and placement rules
TS 12574	Urban transport – Rail transport systems – Part 10: Rules for signage and graphic design within stations
TS 12575	Urban roads – Rail transport systems – Part 11: General rules for system information and notice boards
TS 12511	Urban roads – Rail transport systems – Part 7: Transport system symbols – Design and placement rules
TS 12576	Urban roads – Design rules for structural measures and markings to ensure accessibility on pavements and pedestrian crossings
TS 12460	Urban Roads – Rail Transport Systems – Part 5: Design Rules for Facilities for People with Disabilities and the Elderly

STANDARD NO	STANDARD/REGULATION NAME
TS 9111	Accessibility requirements in buildings for people with disabilities and those with reduced mobility
TS ISO 23599	Assistive products for the blind or partially sighted – Tactile paving markings
TS 13536	Complementary standard for the application of TS ISO 23599
TS EN 81-40	Lifts – Safety rules for construction and installation – Special applications for passenger and goods lifts – Part 40: Escalators and inclined lifting platforms for passengers with reduced mobility
TS EN 81-41	Lifts – Safety rules for construction and installation – Special lifts for the transport of persons and goods – Part 41: Vertical lifting platforms for use by people with reduced mobility
TS EN 81-70	Lifts – Safety rules for construction and installation – Special applications for passenger and goods lifts – Part 70: Accessibility for passenger lifts, including those for people with disabilities
TS EN 115-1	Safety of escalators and moving walkways – Part 1: Construction and installation
Date: 04.06.2010 Number: 27601	Regulation on the Assessment and Management of Environmental Noise (+Regulations Amending the Regulation)
TS 12342	Urban Roads – Rail Transport Systems – Part 4: Design Rules for Maintenance, Repair Workshops and Depots
TS 10551	Urban Roads - Design Rules for Car Parks

The fire safety design of passenger areas, technical areas, operational and staff areas, passenger service areas, and commercial areas opening onto passenger areas in railway stations, as well as facilities along the line, shall be carried out in accordance with NFPA standards. In the fire

safety design of technical/administrative buildings to be designed above ground for the system, the provisions of the Regulation on the Protection of Buildings Against Fire shall be followed.

In areas separated from the station structure by a fire compartment and having an independent entrance, which do not serve the rail system function (e.g. car parks, shopping centres, etc.), the provisions of the Regulation on the Protection of Buildings against Fire shall be the basis for fire safety design.

6.1. STATION PASSENGER LOAD

The spatial design of the station shall be based on the volumes stated in Technical Evaluation Report.

As peak hours at stations located near structures such as stadiums, concert halls, shopping centres, etc., will occur on weekends or during events, these times must be analysed and evaluated when determining peak passenger numbers.

For the permitted passenger density on platforms during normal operating periods, the values specified in TS 12127 and TS 12186 standards shall be used as a basis. These values are 0.35 m²–0.50 m² per person for above-ground stations and 0.50 m²–0.75 m² per person for underground stations.

As the TS Standards do not specify values regarding the area to be allocated per person or passenger load calculations for emergency situations in stations, the values specified in NFPA 130 and NFPA 101 shall be used as a basis for emergency passenger loads and escape distances.

When calculating the ‘net platform area’ to determine the passenger capacity of platforms, the 0.50 m safety zone at the edge of the platform and the queuing areas in front of the stairs shall not be included in the net platform area. Where platforms are located within a tunnel, due to passengers having to walk away from the curved tunnel walls as a result of the head clearance distance, areas where there is not a minimum vertical clearance of 2.00 m on the side of the curved wall shall not be included in the net platform area.

6.2. STATION ENTRANCE/EXIT STRUCTURES

Station entrance structures must be determined by assessing the immediate surroundings of the station within a radius of at least 500 m. Important destinations in the vicinity of the station, such as hospitals, schools and cultural centres, and pedestrian access routes from these points must be taken into account.

The aim should be to ensure integration with public transport modes via the shortest possible route. Space should be allocated near station entrance structures for bicycle and scooter parking

areas and rental units. When making these arrangements, care must be taken not to disrupt existing pavement usage.

When planning the layout of station entrance structures, measures will be taken to reduce expropriation and construction costs, affect as few plots as possible, and carry out pavement and road arrangements for passenger drop-off and taxi bays. Entry and exit tunnels to the station can be designed by evaluating safe and economical alternatives, taking ground conditions into account. Taking into account potential issues that may arise during the construction phase, revisions to the levels and routes of the entrance and exit structures are possible, subject to the approval of the authority and the consultant, provided that this does not increase costs. In the marking of pedestrian pavements and crossings in front of stations, guide surfaces or warning surfaces shall be designed and these designs shall comply with TS ISO 23599 and TS 9111 standards.

Floor coverings used at station entrances and on staircases must be slip-resistant. Rainwater drainage channels must be installed at both the top and bottom of street entrance staircases, extending the full width of the stairs and escalators. Station entrances, lifts, emergency exit structures and technical shafts must be adjusted according to the region's flood level; should a level difference arise between the street level and the station entrance, ramps and stairs must be provided, and queuing distances must be taken into account in the design of station entrances.

Station entrances may be covered for reasons of security, adverse weather conditions, frequent equipment breakdowns, etc.; this matter will be clarified by an administrative decision on a project-by-project basis. In areas where canopies are to be installed at station entrances, and where the efficiency of energy generation has been determined through analyses, PV solar panels may be used, subject to an administrative decision.

At station entrances where canopies are not installed, roller shutters must be fitted in the area where the stairs descend. A passenger information system must be installed in the station entrance area (preferably on the entrance canopy).

For station entrances, materials that are easy to clean, polished, stain-resistant, have low water absorption and high durability should be selected for the parapets of the structures; timber should not be used.

At entrances close to the carriageway, where there is a risk of vehicles veering off the road and entering the station, the parapet may be raised to mitigate these risks.

To ensure the safety, passenger comfort and security of station entrances, they must be adequately lit. Cameras should be positioned to monitor the station entrance staircases and street-level lifts, and at least one of these cameras should be designed as a pan-tilt-zoom (PTZ) camera.

6.3. STATION PLATFORMS

Platform types of stations are indicated in the reference design (conceptual drawings) which is a part of the tender documentation.

6.3.1. Platform Dimensions

Platform dimensions are defined under section 1.8.4.

6.3.2. Platform Design and Layout

Platform design & layout are defined under section 1.8.4.

6.3.3. Capacity Calculation

Platform design & layout are defined under section 1.8.2.

6.4. STAIRS, ESCALATORS AND LIFTS

In the design and dimensioning of stairs, escalators, emergency stairs, lifts and ramps within railway station structures, the conditions set out in TS 12127 and TS 12186 shall be met.

Stair treads must be made of hard, non-slip and matt materials; they must not cause glare or reflection when illuminated by natural or artificial light. Tread edges must not be protruding to prevent tripping. Stair treads must not have open risers.

Grates outside the station must be cast (to ensure strength) and secured against theft using a bolted system. If, due to the risk of theft, plastic-composite grates are to be used instead of cast ones, small-pore, high-strength plastic should be preferred. In railway systems, blockages in drains occur rapidly due to dust and lime in groundwater. Therefore, the diameter of drain pipes for drainage channels at street level and within stations must be of sufficient size. Access hatches must be planned for drainage pipes exceeding 30 metres in length.

Between the fixed staircases leading to the street and the wall/escalator, a gutter may be installed for cleaning purposes, at the discretion of the authority. These gutters along the edges of the fixed staircases must be designed so as not to cause falls and must not extend beyond the level of the handrail.

Where required based on station capacity and evacuation calculations, a protected emergency escape staircase may be provided in addition to the staircases used during normal station operations. A protected emergency escape staircase is a staircase enclosed by fire-resistant materials, designed to allow the safe and rapid evacuation of people in an emergency, and opening onto a secure area at ground level. The walls separating the protected escape staircases from the rest of the building must be fire-resistant for 120 minutes.

Escalators shall be capable of operating in both directions. The incline of the escalators shall not exceed 30°. However, in exceptional circumstances, where there are compelling or restrictive factors within the existing site layout, different inclines may be used in the design. The loading/safety factors for the escalators shall comply with the TS EN 115-1 standard.

In stations where deep levels are unavoidable, access from street level to the platform takes a long time even with escalators; consequently, the proportion of passengers opting for lifts increases in such deep stations. For this reason, lift capacities and numbers should be increased in deep stations. In multi-lift solutions for deep stations, lift capacity calculations must be carried out (taking into account parameters that may affect journey time, such as downtime, boarding and alighting times, and cabin occupancy rates) and supported by travel simulations.

A single lift, escalator or moving walkway—mechanical circulation elements that are prone to failure—between the platform and the ticket hall level must not provide sole access to any part of the station; it must be supported by a staircase or ramp.

Lifts and lift waiting areas shall be positioned so as not to obstruct general circulation routes. Lift shafts should, where possible, be fitted with transparent cladding so that the interior of the lift is visible.

The incline angle of a moving walkway must not exceed 30°, although for a rated speed not exceeding 0.50 m/s and a height not exceeding 6 m, an incline angle of up to 35° is permitted. For moving walkways, the incline angle may be a maximum of 12°.

The carrying capacity of escalators, in accordance with TS EN 115-1, shall be calculated as 120 persons per minute for a width of 1 m and a rated speed of 0.65 m/s; when the rated speed is 0.5 m/s, the capacity shall be 100 persons per minute.

At the start and end of all staircases, ramps and moving walkways, tactile guide surfaces or warning surfaces (HYYİ) shall be installed in accordance with TS ISO 23599 and TS 9111 standards for the benefit of visually impaired persons.

Lifts must be planned so that they are clearly visible within the station and should be located as close as possible to the staircase areas. Taking into account lift maintenance and breakdown procedures, the station should be equipped with preferably two lifts operating between the street-ticket hall and the ticket hall-platform. In stations with significant depth, the number and capacity of lifts should be increased. No more than three lift cabins shall be arranged within the same shaft.

Lift cabins must be of a size that allows a passenger in a wheelchair to turn comfortably (min. 140x200cm), and the lift door width must be at least 110cm. Rather than sliding open to one side, the lift door should open by sliding from the centre to both sides to allow passengers to exit more quickly. Lift cabin doors must be made of transparent glass.

A waiting area of at least 170 cm or at least the depth of the cabin must be provided in front of the lift, both at street level and on the station floors. Where lifts are used for emergency evacuation, all NFPA 130 requirements must be met, and a waiting area of 0.46 m² per passenger must be provided in front of the lift doors.

At least one lift at each station must be designed to accommodate stretcher transport. In lifts suitable for stretcher transport, the cabin width must be at least 110 cm and the cabin length at least 210 cm (TS_EN_81_70 – Table 3). Lift cabin dimensions and cabin design must comply with the dimensions and specifications set out in TS_EN_81_70, TS 9111 and other standards relating to persons with disabilities. Guide paths provided for access by visually impaired persons must be arranged to direct the passenger towards the lift control panel.

Hard, non-slip (wet/dry) and matt materials must be used on ramp surfaces. Necessary drainage measures must be taken at the start and end of ramps and on landings to prevent water accumulation. The length of the ramp surface must not exceed 900 cm; if it does, landings of at least 150x150 cm must be provided. The gradient of ramps located along pedestrian routes must not exceed 5% (1/20). The ramp design must be planned in accordance with TS9111.

Handrails must be installed on both sides of ramps where there is a void on both sides; if the void is on only one side, a handrail must be installed on that side. Handrails must also be installed on the wall sides of ramps. Handrails placed alongside vertical circulation elements must extend for a minimum of 30 cm and an average of 60 cm beyond the end of the element. Handrails at heights of 70 cm and 90 cm must be provided.

The capacity values to be used in the normal operation and emergency evacuation calculations for vertical circulation elements are provided in Annex 1/A: Annex 1/B: and Annex 1/C: .

6.5. TECHNICAL AREAS

In addition to the areas used by passengers in railway stations, there are also technical areas required for electrical, electronic and mechanical systems. The TS12127 and TS 12186 standards will also be taken into account in the design of these areas.

In railway stations, which are predominantly designed underground, the design of station and tunnel ventilation systems is of paramount importance; alongside ventilation systems, fire suppression systems, plumbing, and drainage systems are key topics in mechanical design.

Electrical and electronic systems, on the other hand, encompass the design of the power supply system for vehicles on the line, the regulation of daily and emergency power requirements for stations and the line, power supply systems, signalling systems, and control and communication systems such as public address systems and CCTV systems.

Wet areas must not be installed above or near electrical/electronic equipment rooms. In stations designed entirely as open-air structures, wet areas must not be installed on the floor above the platform level, or above or near the track axes.

While some technical areas in stations are required in every station, others may vary depending on the requirements of the line.

Important considerations regarding the locations, minimum floor area and room height specifications, and the design of rooms for electro-mechanical areas within stations are provided in the tables below. Whilst the required areas may increase depending on the size of the station, they must not fall below the areas specified in the table.

Shafts opening onto street level and emergency exit structures must be designed at ground level in accordance with the existing site layout. In ground-level shaft arrangements, necessary drainage measures must be taken on and around the relevant shaft floor to account for any flooding or overflow. If the shafts are located within a green area, a parapet of at least 30 cm may be constructed depending on the site's gradient and rainfall characteristics. Beneath the top grille of the shaft, a mesh or grille cover shall be installed (approximately 100 cm below the top grille) to retain incoming debris and provide a secondary safety measure. Anti-theft details shall be incorporated for the shaft covers.

Measures will be taken around all at-grade shaft covers and emergency exit covers to prevent vehicles from parking on them or blocking them.

The required spaces for electrical and electronic systems in stations are provided as examples in Table 6.2. Space requirements shall be determined and verified by means of room layoout drawings prepared by the Contractor, refering to the;

- Functions provided in the Station,
- Main power supply possibilities at the Station vicinity,
- Continuity and reliability of the main power supply.

The required spaces for mechanical systems at stations are provided as examples in Table 6.3. Space requirements must be determined based on the design.

Table 6.2 : Electrical and electronic system locations

Area Name	Area Location	Station Location	Number of Rooms	Minimum Area/Height	Comments	Raised Floor
MV-LV Equipment Room*	Single Transformer Centre Equipped Station	In the centre of the station	1 unit	270 m², 5 m	-Equipment room doors must be of the panic bar type to ensure they can be opened quickly from the inside in the event of an emergency. -Equipment rooms must be located away from wet areas. -Openings in the floor for transformer track rails must be covered with removable covers, and where possible, there should be no level differences within the room for equipment evacuation; if this is not possible, low-angle concrete ramps must be constructed. These rooms should be designed to be as large as possible and, in underground stations, situated in areas with ground contact to dissipate heat loads.	Preferably, a cable gallery/raised floor or concrete cable duct should be installed; if this is not feasible, a raised floor at a minimum height of 80 cm above the ground . The support bases for MV switchboards must be installed so that they extend 2 metres further towards the front of the switchboards to allow for the movement of the switch trolleys. In the event of a low-level floor installation; * the height must be 150 cm * a ship's ladder must be provided * A connection must be provided between the cable shaft and the low floor via. * Details regarding cable entry and exit points to the lower deck, as well as a
MV-LV Equipment Room*	Station with a Main Power Supply, Single-Transformer-Centred, Equipment	In the centre of the station	1 unit	350 m², 5m		
MV-LV Equipment Room*	Dual-Transformer Centre Equipped Substation	In the centre of the relevant section of the station	1 unit	350 m², 5 m (with traction equipment)		
MV-LV Equipment Room*				210 m², 5 m (without electrical equipment)		
MV-LV Equipment Room*	Dual-Transformer Centre Equipped Station	In the centre of the relevant half-section of the station	1 unit	210 m², 5 m		

Area Name	Area Location	Station Location	Number of Rooms	Minimum Area/Height	Comments	Raised Floor
MV (LV) Equipment Room*			1	210 m², 5 m		vertical access ladder, must be taken into account in the design.
Battery Room (for power UPS and 110V DC battery chargers)	All stations	MV- LV Equipment Room and Room side by side	As many Equipment Rooms as required	40 m²	Power UPS and 110V Battery rooms for DC battery chargers and batteries will be located as separate rooms adjacent to the MV-DC-LV Equipment Room and the MV-LV Equipment Room, near the area housing the LV equipment; access to this battery room will be via the technical corridor. The battery room for the Signalling UPS and the Control & Communication UPS batteries and equipment will be accessed via the technical corridor.	None
Battery Room (for the batteries of the signalling UPS and Control & Communication UPS)		The Signal Room and Room	1 unit	16 m² 8 m² each (if designed as separate rooms)		None
Electrical Panel Room (Secondary distribution panels)	All stations	In the centre of the station	As many as there are concourses on each floor	8 m²		None

Area Name	Area Location	Station Location	Number of Rooms	Minimum Area/Height	Comments	Raised Floor
Electrical Switchboard Room (Situation where platform sub-distribution boards and tunnel/viaduct sub-distribution boards are located in a single room)	All stations	On the platform level, between the platform end door and the tunnel entrance	Or two units	12 m² each	On the platform level, if the distance between the platform end door and the tunnel entrance is less than 30 m, the station secondary distribution boards and the tunnel secondary distribution boards may be located in the same room.	None
Electrical Panel Room (for tunnel/viaduct secondary distribution panels)	All stations	On the platform level, between the platform end door and the tunnel entrance	One or two	8 m² each		None
Commercial Areas Electrical Room	Stations with commercial areas	In the centre of the commercial areas it supplies	1 unit	if the number of commercial units is ≤ 10, 10 m²; If the number of commercial units is 10 < number of commercial units ≤ 15, then 15 m²; If the number of commercial units is greater than 15, 20m²	If there are a large number of commercial areas, this room must be constructed; in principle, commercial areas will be supplied from the nearest electricity company's substation, independent of the metro's electrical system. For this purpose, an electrical shaft of at least 50x50cm must be constructed from this room down to ground level.	None

Area Name	Area Location	Station Location	Number of Rooms	Minimum Area/Height	Comments	Raised Floor
Station Control Room (SOR)	All stations	Preferably on the ticket hall level, in a position to overlook the turnstiles,	1 unit	30 m²	This is the room where station security cameras are monitored and must be situated in a location with a view of the turnstiles. In stations with integrated systems, designing a single Station Control Room (SOR) is sufficient.	Available
Communications Room	All stations	Preferably on the ticket hall level, adjacent to the SOR and, where possible, situated close to the electrical cable shaft.	1	40 m² 60 m² (at stations with integration)		Available
Signalling Room	All stations	In an area on the platform level protected from tunnel/viaduct effects or on the ticket hall level Adjacent to the Communications Room	1 unit	25 m², 5 m (driverless system – UTO) 40 m², 5 m (system with driver)	If installed on the ticket hall level, it should be planned close to the Station Control and Communications room.	Available
GSM Room	All underground stations	In the uncontrolled area on the ticket hall level,	1 unit	20 m² (for GSM operators)	Access to street level in a location close to the equipment shafts	None

Area Name	Area Location	Station Location	Number of Rooms	Minimum Area/Height	Comments	Raised Floor
Fibre-optic cabinet room	All stations	It is preferable for it to be adjacent to the GSM room is preferred	1 unit	20 m², 3 m	On a floor close to ground level or with access to the ground Near equipment shafts	None
Turnstile Equipment Room	All stations	On the Ticket Hall level, immediately adjacent to each entry-exit turnstile group	The number of entry-exit turnstile groups equal to the number of	6 m²	It is preferable to position them in an uncontrolled area.	None
OCC (Main Control Centre)	Typically warehouse areas (or a different location depending on the design)	Depends on the design	Depends on the design	Will be determined based on the size of the railway line and whether it is driverless or not.		If constructed, it will be at least 50 cm above ground level.
OCC Main Equipment Room	The building housing the OCC	Adjacent to the OCC	The number of OCCs	To be determined based on the size of the railway line.	The OCC Main Equipment Room and the Depot Communications Room may be designed as separate rooms, or they may be combined into a single room adjacent to the OCC. In this case, the combined room will be designated	A raised floor (at least 50 cm above ground level raised flooring will be installed.)
Warehouse Communications Room	In a suitable area within the Depot-Maintenance Area	Depends on the design	Subject to design	To be determined depending on the size of the railway line.		Yes (A raised floor at least 50 cm above ground level a raised floor will be installed.)

Area Name	Area Location	Station Location	Number of Rooms	Minimum Area/Height	Comments	Raised Floor
Central Communications Room	The building housing the OCC	Adjacent to the OCC	As many as there are OCCs	Depending on the size of the railway line, at least 60 m²	as the Central Communications Room. If two separate rooms are designed in the Depot-Maintenance Area as the OCC Main Equipment Room and the Depot Communications Room, there will be no Central Communications Room. If there is a Central Communications Room, however, there will be no other communications room in the Depot-Maintenance Area.	(A raised floor at a minimum height of 50 cm above ground level)
Central Signalling Room	The building housing the OCC	Adjacent to the OCC	The number of OCCs	To be determined based on the size of the railway line and whether it is driverless or not.		Yes (A raised floor at a minimum height of 50 cm)
PSDS Panel Room	All stations (UTO – on driverless lines)	On the platform level	1 unit	20 m²	For the implementation of driverless railway systems, the installation of PAKS on platforms is mandatory. The PAKS control room should preferably be located in the centre of the platform.	None

Area Name	Area Location	Station Location	Number of Rooms	Minimum Area/Height	Comments	Raised Floor
Cable shaft	All stations	“Top floor ceiling – MV/DC/LV equipment rooms – Under the platform” NOTE: If a continuous vertical route cannot be provided, combinations such as vertical+horizontal+vertical, etc. . The aim here is to reach the platform level and the top floor.	The number of equipment room	3 metres in diameter (if circular) or In stations with single or double transformer-centred traction equipment 12 m² (rectangular, 3m x 4m) In single and double transformer-centred stations without traction equipment 8 m² (rectangular, 2 m × 4 m) Larger dimensions may also be required depending on cable density. As the number of cables for the DC Panel Group and the LV Main Distribution Board is very high, the cable shaft must be positioned close to this equipment .	Staff must have access to the shafts. To this end, a protected vertical ship’s ladder must be installed along the entire length of the shaft, and a steel platform must be provided every 3 metres. The protected vertical ship’s ladder must be installed in a staggered manner between the steel platforms.	

Area Name	Area Location	Station Location	Number of Rooms	Minimum Area/Height	Comments	Raised Floor
Equipment Shaft	All stations	OG-DC-AG Equipment Room will be located	OG as many equipment rooms as there are	In single and double transformer-centred substations: (rectangular, 3.5m x 4.5m) Or In single and double transformer-centred stations without electrical equipment: (rectangular, 3.5m x 3.5m)	If the dimensions and locations are suiable for equipment access, mechanical shafts (TVF, IHF, etc.) may be used as equipment shafts; in this case, there is no need to construct additional shafts. However, the necessary infrastructure (transformer running rails, calaskar, etc.) must also be installed.	
Under the Platform	All stations				As the areas beneath the platforms are located along the cable route leading to the tunnel or track, they are subject to heavy cable traffic and must be designed to a depth of at least 170 cm to accommodate cable duct installation and provide access.	

* These rooms may be designed such that transformers, MV equipment, LV equipment and, where applicable, DC equipment are housed together in a single room of the same volume; alternatively, they may be arranged as two separate adjacent spaces, with MV equipment, transformers and, where applicable, DC equipment in one space and LV equipment in a separate space.

Table 6.3 : Mechanical system rooms.

Room Name	Room Location	Location within the Station	Number of Rooms	Minimum Area/Height	Comments
General Ventilation Room	All stations	Station Open-Close Structure (Technical Floor)	Depends on the design	200 m²	A shaft must be designed to distribute the open-close structure of the ventilation ducts exiting this room to the respective floors. This shaft should be positioned close to the general ventilation room (preferably within the room). The dimensions of the room and shaft will be finalised on a project-specific basis.
General Ventilation Room **Exhaust** Air Shaft	All stations	General Ventilation Room (Leading to the street)	1 unit	5 m²	These two shafts must be positioned within the general ventilation room with a minimum distance of 5 m between them. The shafts must be enclosed by walls, with access provided via a door. At street level, the tops of the shafts will be covered with a metal grille; for safety purposes, a second grille (with wider mesh) will be installed 100 cm below.
General Ventilation Room **Fresh** Air Shaft	All stations	General Ventilation Chamber (Leading to the street)	1 unit	5 m²	
TVF shaft from the platform	Underground stations	Between the platform and the TVF shaft room	Depending on the design	20 m² (Subject to revision based on analysis.)	The TVF shaft will be located in the area beyond the platform end door; if the TVF Room is designed on the platform level, this shaft will not be required, and instead, hatches opening onto both tracks will be installed. This shaft should be designed to be as non-displacing as possible.
TVF Room	Underground stations	1. Preferred Open-Close Structure 2. Preferred Platform Level Tunnel	Depending on the design	10 x 11.5 m	In the ideal solution, the room should be accommodated within the station's open-close structure; alternatively, if suitable space is available at street level, a separate TVF open-close structure should be constructed; as a last resort, this room will be designed within the large-section tunnels on the platform level. TVF shaft rooms will be positioned in front of and behind the TVF room, and the shafts will open directly into these rooms. Doors will be installed to provide access to both sides of the TVF equipment.

Room Name	Room Location	Location within the Station	Number of Rooms	Minimum Area/Height	Comments
TVF Shaft Leading to Street Level	Underground stations	Between the TVF Shaft Room and the Street	Depending on the design	20 m² (Subject to revision based on analysis.)	The shaft will lead from the TVF shaft room to the street.
General Areas Ventilation Shaft Room from the Platform	Underground stations	Between the platform and the shaft room	1	8 m²	The General Areas Ventilation Shaft must extend from the floor where the ventilation room is located down to the ceiling of the lowest-level platform. The shaft should preferably be positioned to centre the station.
General Areas Ventilation Room	Underground stations	Station Open-Close Structure (Technical Floor)	1 unit	9.5 x 9.0 m	
General Areas Ventilation Shaft Leading to the Street	Underground stations	Between the IHF Shaft Room and the street	1 unit	8 m²	The shaft will lead from the General Areas Ventilation shaft room to the street. At street level, the tops of the shafts will be covered with metal grilles; for safety purposes, a second grille (with wider mesh) will be installed 100 cm below.
Escalator Panel Room	All stations	On the floor where the escalators descend, near the escalator	Depending on the design	8 m²	Where possible, these rooms should be installed directly beneath the escalators. The control panels for escalators installed in tunnels may be housed in lockable cupboards on the floor where the escalator emerges, close to the escalator. The control panels for escalators at street-level entrances, however, will be installed on the floor where the escalator descends.

Room Name	Room Location	Location within the Station	Number of Rooms	Minimum Area/Height	Comments
Water Tank and Pump Room	Depending on the design	Station Opening-Closing Structure, on the lowest floor	1 unit	Depending on the design/calculation	It is preferable to install it on a floor resting on the ground. The water tank, the volume of which will be calculated according to the station, should be designed in two sections, and access to the tanks should be provided via a ship's ladder for cleaning operations.
Wastewater Pump Room	All stations	Close to WCs and wet areas, (if applicable) on the lower level of these areas	Depending on the design	15 m²	This is the room where drains from wet areas and toilets are collected and pumped into the sewers. The requirement for a sump and its size will be assessed on a project-specific basis. This room must not be situated above electrical and electronic rooms or the water tank, and this rule applies to all other wet areas.
Drainage Pump Room	All stations	Near the Station Entrance Staircase, on the Floor Where the Staircase Descends	Depending on the design	10 m²	This room collects water and leakage from the rainwater and fire-fighting systems and directs it to the drains. It must not be located above the electrical and electronic rooms or the water tank. The drainage pit inside the room will be covered with a grate.
	All stations	At the end or centre of the platform	Design-dependent	15 m²	To be positioned diagonally at the start and end of the platform, close to the track. The pit to be installed within the room will be covered with a grating, and access to the pit will be provided via a ship's ladder.
Drainage Pit (Platform)	All stations	Inside the Drainage Pump Room (Platform)	Depending on the design	10 m² (5x2 m), Depth 5 metres (from the platform's low level)	Consists of two sections: a sedimentation and holding pit. Access to the drainage pit section must be possible via a ship's ladder.

6.6. OPERATIONAL AREAS

Operational areas are spaces to be used by the railway line operator's staff. Most of these areas will be located on the ticket hall level. These areas should be planned in close proximity to the station control room and, where possible, in such a way as to avoid overlapping with technical areas.

In particular, the staff room should be situated close to the station operations (control) room, and a corridor should be provided between it and the passenger areas (Figure 6.3).

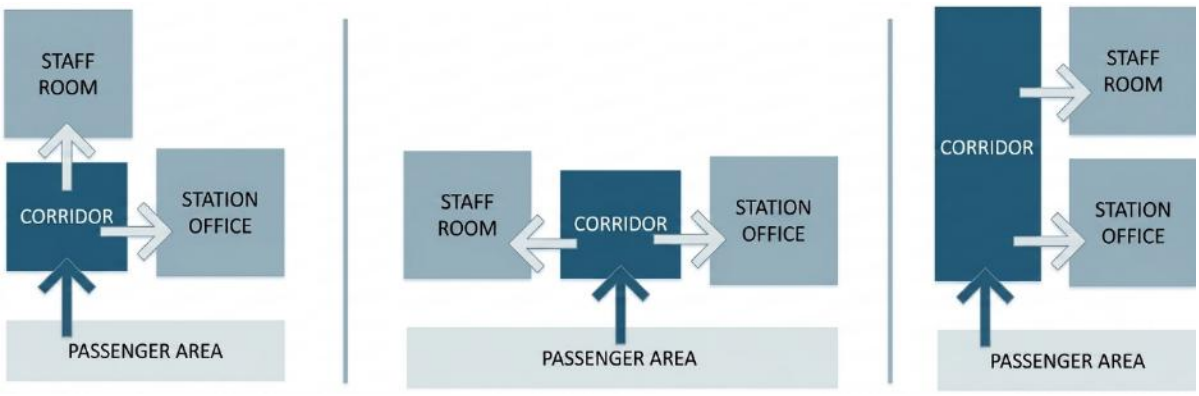


Figure 6.1 : Staff room and station operations (control) room solutions

There are also operational areas located on the platform level at stations. The driver's cabs planned for the first and last stations on the line must be arranged to include the areas specified in Table 5.4 in order to meet the needs of train drivers.

Table6.4 : Areas and spaces within the driver's cab (on driver-operated lines)

FIRST STATION OF THE LINE		THE LINE'S FINAL STATION	
Area Name	**Area (m²)**	**Area Name**	**Area (m²)**
Engineer's rest room	30	Rest room	15
Dining service area and	20	Men's washroom area + WC	2 Cabins
Men's engine room changing	15	Ladies' washroom area + WC	1 cubicle
Ladies' crew changing room	10		
Prayer room	15		
Men's WC	3 cubicles		
Ladies' WC	1 cubicle		

All necessary areas for station operations/staff are provided in Table 6.5.

Table 6.5 : Station operations/staff areas

Area Name	Area Location	Location within the Station	Number of Rooms	Minimum Area/Height	Comments
Driver's Cab (On Driver-Operated Lines)	At the start and end stations of the line	On the platform level, On the track side where the train will run	2 units (one at each of the first and last stations)	Area information regarding these locations is provided in Table 6.4 at.	These areas will be designed at the start and end stations of the line. These areas must be situated on the side of the track where the train will run and close to the driver's cab. Within the driver's cabin, a rest room, men's and women's changing rooms, a tea room, a kitchen, men's and women's toilets, and a prayer room must be planned together.
Staff Rest Room	All stations	On the Ticket Hall Level, near the Station Control Room	1 unit	20–30 m²	The Station Control Room and Staff Rest Room should, if possible, be adjacent or in close proximity. The staff rest room serving station staff will consist of a kitchen, a tea station and a relaxation area.
Staff Changing Room + WC	All stations	Preferably on the Ticket Hall Floor, Technical Floor if space is limited	2 units	15 m² + WC area	Separate changing rooms must be provided for security staff. Separate men's and women's WCs must also be designed nearby; for men, at least two cubicles (one Turkish-style, one Western-style) and for women, at least one cubicle must be provided. In stations with a large number of staff, the number of cubicles may be increased.

Area Name	Area Location	Location within the Station	Number of Rooms	Minimum Area/Height	Comments
Staff Prayer Room	All stations	Near staff rest or changing rooms	2 units (Separate for men and women)	10–15 m²	Staff prayer areas should also be planned close to the rest rooms. If space permits, an ablution basin may be installed within them.
Station Cleaning Room	All stations	Near wet areas	Depending on the design	16 m²	It must contain hot water plumbing, a mop washing basin and storage cupboards. In addition to this large cleaning room, which will house the station's cleaning equipment, smaller cleaning rooms (5–6 m²) will be provided in the WC areas.
Passenger WC - Staff Room	All stations	On the ticket hall level in the unrestricted area, at the entrance to the passenger WC area	1 unit	10–15 m²	Should the operation of the passenger toilets be outsourced to another company, a turnstile system for paid access to the toilets will be designed. The disabled toilet and baby care room must be designed before this turnstile. This turnstile will also be suitable for disabled access. The staff room must be positioned so that it overlooks this turnstile. This room will also be used to store the necessary supplies and cleaning equipment for the toilets.

6.7. PASSENGER SERVICE AREAS AND STATION FACILITIES

Passenger service areas and station facilities generally include:

- Passenger information desks,
- Passenger toilets
- Prayer rooms (including ablution facilities)
- Baby care room
- First aid room
- Ticket machines,
- Public telephones,
- Newspaper, food and drink vending machines,
- Bank ATMs,
- Rentable (commercial) spaces and kiosks,
- Seating areas,
- Rubbish bins,
- Passenger guidance signs.

At each station, toilets catering for male, female and disabled passengers must be provided. Toilets must be located within an unrestricted area, and a sufficient number of male and female toilets will be provided. Decisions and implementations regarding passenger toilets shall comply with the conditions set out in TS 12127 and 12186. As a general rule, two cubicles (one Turkish-style, one Western-style) and two washbasins shall be planned for both men and women. At interchange stations, the number of cubicles and washbasins may be increased according to the specific requests of the operator and management.

One accessible toilet shall be provided at each station. This toilet shall be located in the same area as the other toilets, and users with reduced mobility shall be able to locate and use the accessible toilet within the station as easily as other passengers. The accessible toilet shall comply with TS 9111 standards. To ensure that visually impaired or partially sighted passengers can easily identify them, door-opening fittings must be selected in a colour contrasting with the door leaf. The door lock must be equipped with a mechanism that can be operated from the outside in the event of an emergency requiring intervention.

Subject to the views of the Administration and the Operator, prayer rooms shall be constructed in the unrestricted area for use by staff and passengers, and there shall be a place for ablution at their entrances. Prayer rooms and ablution facilities shall be designed separately for women and men.

A first-aid room, containing a stretcher, first-aid cabinet and washbasin, shall be planned on the ticket hall level, close to the station control room and accessible from the unrestricted area, to enable initial assistance to be provided to passengers and staff in emergencies.

A baby care room, containing a washbasin, a nappy-changing table and a seating area for breastfeeding, will be designed in the unrestricted area, near the passenger toilets, for use by passengers.

Leasable (commercial) areas and kiosks will be planned in the unrestricted area, particularly at stations with high passenger volumes and transfer stations, in accordance with the requirements of the operator and management. Where there are counters serving products on the front of these commercial areas, it must be anticipated that passengers will wait there; they must therefore be positioned so as not to disrupt passenger flow, with a queuing area left in front. Commercial areas and any queues that may form in front of them must not be located in the queuing areas of staircases, turnstiles or escalators. When planning commercial areas, the necessary measures must be taken in accordance with fire safety regulations.

Station staff members planned to serve passengers on the station ticket hall level must not be positioned on passenger flow routes and must not restrict the space requirements of other areas within the turnstile zone. The number of these station facilities will be determined according to passenger numbers, and queuing areas must be provided in front of devices where passengers are expected to wait, such as ticket machines and ATMs.

Ticket machines must be positioned so as not to obstruct passenger flow; however, they must be located close to the turnstile area and within the staff member’s line of sight to enable staff to assist passengers should they require help.

Seating units will be located on the platform level, not in the turnstile area. In each section where seating groups are situated, at least one space suitable for a wheelchair must be provided. If there are not a sufficient number of seating units, they must be marked to indicate that priority is given to passengers with disabilities, the elderly, pregnant women and those with children. The underside of seating groups must be designed to be visible or monitored by CCTV for security purposes, without creating a security vulnerability.

All station fixtures must be securely and permanently fixed to the floor, walls or columns. The design and installation of fixtures must incorporate measures against theft and vandalism, and be planned to facilitate maintenance processes. All fixtures within the station must be positioned so as not to obstruct passengers’ ability to read information displays.

From the street entrance to the platform, from train to train, and from the train to the street exit, there shall be signage, signs and symbols along the passenger route and all passageways. Safety information and instructions, signs indicating warnings, prohibitions and requirements,

information screens displaying train departure times, and signs explaining, indicating the location of and guiding passengers to areas within the station shall be installed.

The average eye level of a standing person is between 120 and 160 cm above the ground. Therefore, identification signs on doors or information boards on walls intended to be read at close range must be mounted within this height range.

Signs indicating passenger service areas should use symbols to support the text, ensuring that passengers whose first language is not Turkish and who have difficulty understanding the concepts can also comprehend the information provided. However, in situations where passengers can understand the information without words, symbols alone may be used.

In addition to directional and information signs, there should be a sufficient number of information boards (infopanels) in stations that passengers can easily access.

Braille (for the blind) raised-letter signs should be used on directional signs, room nameplates, emergency call devices, next to toilet doors to indicate the type and gender of the toilet, and on handrails to guide visually impaired passengers in using station areas where they may require assistance. Raised-letter signs must be sufficiently raised so that the information or symbols provided are easily understood. The raised sign should be positioned on the wall on the side of the door handle, at a height of 120–160 cm. In toilets and washrooms, it may be located on the door itself. All designs in this regard must comply with TS 9111 standards.

6.8. INTERIOR ARCHITECTURE AND MATERIALS

In the design of high-traffic railway stations used by thousands of people every day, passenger and system safety, fire and emergency scenarios, and passenger evacuation are the primary factors determining the structural design. Material choices are also shaped within this framework.

The general approach to railway station design is that cladding materials should be durable, easy to maintain, environmentally friendly, non-combustible or possessing the required level of fire resistance, cost-effective, and visually appealing.

Materials used for all elements in stations—including flooring, walls, ceilings, stairs, platforms, doors, etc.—must be durable and safe against fire, wear, deformation, scratching, impact, water, moisture and slipping, and must be aesthetically pleasing. They must also comply with relevant national and international standards regarding various characteristics such as ease of maintenance, repair and renewal.

In the wall and ceiling cladding of railway stations, the use of non-combustible (materials that do not ignite, burn, support combustion or emit flammable smoke when exposed to fire or heat) or limited-combustible materials shall be permitted (NFPA 130 – 5.2.5.1).

In accordance with NFPA 130 – 4.6*, materials that meet the requirements of NFPA 101 – 4.6.14 shall be considered limited-combustible.

In railway stations used by thousands of people every day, carcinogenic materials and materials that emit toxic gases shall not be used, both for the sake of user health and for the purposes of emergency evacuation.

The maintenance and refurbishment processes of materials or products are a key selection criterion for railway stations. In railway stations designed to last for over 100 years, it is inevitable that cladding materials will need to be replaced or renewed several times. However, to minimise these maintenance and renewal activities in operational stations, high-performance materials with a long service life should be preferred.

In rooms housing electronic equipment, control rooms and control systems where dust and dirt control is required and raised flooring is installed, the areas beneath the raised flooring must also be covered with epoxy flooring.

In underground stations, the cladding of external retaining walls in contact with the ground should, due to the water and moisture issues that typically arise, and for reasons of both the cladding's durability and passenger safety, favour mechanically fixed installations over adhesive-bonded panel cladding. Solutions must be considered to provide access to the electro-mechanical infrastructure running behind the cladding, which may require maintenance and repair.

Large panels exceeding human carrying capacity necessitate the use of machinery during both initial installation and subsequent repair processes. The cladding/panels used for wall and ceiling cladding should be selected in an optimal size: large enough to minimise joints and seams, yet small enough to facilitate the removal, transport and replacement of a panel should it be damaged.

To counter graffiti and vandalism, materials that can be easily cleaned using standard maintenance techniques should be used. Station cladding materials and surfaces must be resistant to chemical degradation caused by substances such as chemicals, cleaning agents, salt and grease.

Care should be taken to select materials that do not easily become soiled or stained, can be easily cleaned with standard cleaning products, and do not show minor stains. Platform-level cladding is constantly exposed to dust due to the air swept up by the train. Smooth surfaces should be preferred as they retain less dust.

The wear resistance of materials and surface finishes is of paramount importance. In addition to pedestrian traffic, the impact of vehicles used within the station for cleaning and maintenance purposes must also be taken into account.

In passenger areas of the station, sound insulation materials made from suitable materials that reduce vibrations and absorb sound will be used to ensure announcements are clearly audible and acoustic comfort is provided. Materials selected for acoustic improvements and noise control must also be non-combustible or limited-combustibility materials that meet the requirements of NFPA 130.

Furniture used in stations, including seating benches, fixed litter bins and staff changing room lockers, shall also be manufactured from non-combustible materials (NFPA 130 – 5.2.7).

As part of the adaptation of sustainable design approaches to railway stations, local materials should be prioritised, and recyclable, low-energy-production, and high-recyclability materials/equipment should be preferred.

6.9. ACOUSTIC DESIGN

Acoustic design is defined under section 1.8.5.

6.10. ADDITIONAL MEASURES FOR PEOPLE WITH DISABILITIES

Additional measures for people with disabilities are defined under section 1.8.9.

6.11. STATION CAPACITY CALCULATION

Station capacity calculations are defined under section 1.8.2.

7. ELECTRICAL SYSTEMS

7.1. PURPOSE & SCOPE

This section of the document has been prepared as a guide to explain the design requirements for the electrical systems to be installed on newly designed railway lines within the borders of the Republic of Türkiye, and contains the assumptions, variables, data, codes, standards and other documents on which the electrical installation is based, in accordance with the Authority's requirements. The conditions set out in this section may be applied not only to newly designed lines but also to renovation and improvement works on existing railway lines.

The design of the Railway lines must be carried out in accordance with these basic design requirements and the relevant current standards and regulations. However, in cases of necessity, such as technological developments, new application methods, or updates to reference standards/legislation, changes may be made with the Authority's approval.

The aim is for the designs to be contemporary, functional, cost-effective, durable, reliable, and of high quality, whilst being appropriate to urban and social characteristics.

Another criterion to be considered in the design is the flexibility of the selected systems and their suitability for future growth. Flexible solutions must be designed for both distribution systems and the selection of equipment capacities to accommodate future growth and changes.

7.2. ADMINISTRATION REQUIREMENTS

The design of works reflected in the specifications, and all other design-related documents required for the completion of the works must ensure that the works fulfil their intended purpose. The intended purpose of the works shall be based on the principle that what is designed and implemented must be safe, sound, reliable and durable.

The following principles shall be adhered to:

- The design shall always be compatible with the construction methods to be used and local practices.
- New solutions within industrial methods and current technology shall be adapted where practical.
- The design, materials and construction methods shall be recognised and proven.
- The design shall be safe.
- The design shall be flexible in the face of unforeseeable and changing electrical conditions of a reasonable magnitude.
- Construction and manufacturing risks must be assessed and quantified in terms of probability and frequency of occurrence.

- Structures will be designed to facilitate manufacturing and allow for modification, inspection and maintenance.
- The design must take into account user safety, the necessary arrangements for maintenance and operating personnel, and the manufacturing process.
- In the design of all electrical equipment, consideration shall be given to issues relating to quality, performance and functional losses in the electromagnetic environment generated by the system.
- Measures will be taken to ensure that the electromagnetic environment in which the equipment operates does not have an adverse effect on its performance. Measures will be taken in the design to minimise electromagnetic interference radiated into the environment. (For example: installing cables belonging to low-voltage systems and cables belonging to high-voltage systems in separate cable trays/channels/pipes/ladders; laying power cables and control cables separately, etc.)
- EMC requirements will be adhered to at the intersection points of cables belonging to different systems, and measures will be taken to prevent electromagnetic interference.

7.3. STANDARDS & REGULATIONS

In the design of electrification systems, the standards/regulations/codes listed below (without being limited to these) shall generally be taken into account. Standards/regulations/codes specific to a particular system are not included in this list but are provided under the respective system's heading.

- Turkish Standards (TS)
- European Standards (EN)
- International Electrotechnical Commission (IEC) Standards
- National Fire Protection Association (NFPA) Standards
- International Organisation for Standardisation (ISO) Standards
- American National Standards Institute (ANSI) Standards
- British Standards (BS)
- French Standards (NF)
- German Institute for Standardisation (DIN) Standards
- VDE Standards
- Institute of Electrical Engineers (EMO) Regulations and By-laws (Regulations on High-Voltage Electrical Installations, Regulations on Electrical Installations, Regulations on Earthing in Electrical Installations, etc.)
- Regulations on the Fire Protection of Buildings

- TEDAŞ Specifications and Regulations
- Low Voltage Regulation
- Regulations of the Illuminating Engineering Society (IES)
- Regulation on Electrical Installations

Of the references listed above, the legal regulations applicable in Turkey—namely the "Laws, Decrees, Statutes, Regulations and Notifications of the Republic of Turkey" and the Rail Systems Regulations—take precedence. Where the Laws, Decrees, Statutes, Regulations and Notifications of the Republic of Turkey are insufficient, International Regulations, Standards and Specifications shall be used, with priority given to European Standards (EN) and the International Electrotechnical Commission (IEC).

The most up-to-date versions of all references provided above shall be used.

7.4. GENERAL

In all sections of the facility at HV, MV and LV voltage levels, short-circuit currents, voltage drops, transient overloads and the heating of facility components (transformers, rectifiers, busbars, cables, etc.) shall not exceed the permitted limits.

Prior to commencing the design works, the Contractor shall prepare a design manual outlining the rules and standards to be considered, as well as the criteria and methodologies to be applied in the design of electrical systems and submit to the Engineer for approval.

In suitable locations and systems, different power supply solutions can be implemented using renewable energy sources (wind, solar, etc.) and regenerative energy.

All electrical alarm information and electrical interlocks shall be obtained via dry contacts and digital signals via closed contacts (position 1), and the necessary infrastructure shall be installed in accordance with the fail-safe principle to ensure safety against faults.

The project-specific document and equipment coding procedure documents will be prepared and submitted to the Authority for approval.

7.5. TECHNICAL AREA REQUIREMENTS

The technical areas for electrical systems within the traction power substations, stations, and wayside technical buildings, that will be constructed along the project scope railway line, where HV/MV/LV and communication/signalling system equipment will be installed, shall be dimensioned in accordance with the principles specified below:

7.5.1. General Requirements

- The design shall comply with applicable IEC and EN standards for electrical installations, safety, and accessibility, including general principles from:
    - IEC 61936-1 / EN 61936-1 (Power installations exceeding 1 kV AC)
    - IEC 60364 series (Low-voltage electrical installations)
- Equipment rooms shall ensure safe operation, maintenance accessibility, and efficient spatial organisation.
- Electrical equipment rooms shall comply with the related standards for protection against external influences.
- Wet areas shall not be located above or adjacent to electrical rooms.
- Design shall mitigate risks related to moisture, flooding, and environmental exposure.

7.5.2. MV-LV Equipment Room

7.5.2.1. Location and Arrangement

- The equipment room shall be located to ensure optimal integration within the substation layout, preferably centrally positioned.
- Equipment arrangement shall prioritise:
    - Safe access and maintenance (IEC 61936-1 principles)
    - Functional grouping of MV and LV systems
- A single combined room for transformers and MV-LV equipment is preferred to optimise space and operational access.
- Separation into multiple rooms may be applied where required by design constraints or safety considerations.
- Where applicable, installation shall include:
    - Elevated access solutions (e.g. gallery or raised floor) to facilitate cable routing and maintenance

7.5.2.2. Access and Handling (Material Shaft)

- Access provisions shall enable safe installation, removal, and replacement of heavy equipment in accordance with:
    - IEC 61936-1 (handling and installation principles)
- Material shafts shall:
    - Provide direct access from ground level

- Be located to enable safe and practical logistics operations
- Be positioned near accessible external areas where feasible

7.5.2.3. Structural and Installation Requirements

- Equipment support and mounting systems shall comply with:
  - IEC 61936-1 (mechanical strength and installation requirements)
- Heavy equipment shall be installed on load-bearing structures appropriate to operational loads.
- Raised floors or equivalent solutions shall be implemented where required for cable management and equipment installation.
- Equipment mounting shall ensure:
  - Mechanical stability
  - Safe operational clearance
  - Accessibility for switching operations

7.5.3. Secondary Distribution

- Sub-distribution systems shall be provided in accordance with:
  - IEC 60364 (distribution and protection principles)
- Electrical panels shall be distributed across levels based on operational requirements.
- Panel rooms shall:
  - Ensure safe access and segregation of functions where required
  - Allow combined installation of compatible systems when operationally justified

7.5.4. Commercial Electrical Supply

- Where commercial areas exist:
  - Electrical systems shall be designed independently from railway systems in accordance with IEC 60364 principles
- Dedicated electrical rooms and routing provisions (e.g. shafts) shall be provided to ensure separation and maintainability.

7.5.5. Control, Communication, and Signalling Rooms

- Critical operational rooms shall be co-located where possible to:
  - Minimise cabling complexity
  - Improve system integration and operational reliability

- Design shall align with functional safety and system coordination principles (IEC system integration practices).

7.5.6. Battery and UPS Systems

- Battery installations shall comply with:
    - IEC 62485 series (Safety requirements for batteries and battery installations)
- Battery rooms shall:
    - Be located close to associated UPS systems
    - Allow safe cable routing within practical limits
    - Ensure adequate ventilation, safety clearances, and maintenance access

7.5.7. Diesel Generator Rooms

7.5.7.1. Location and Arrangement

- The diesel generator room shall be located to ensure optimal integration within the substation layout, preferably in the close vicinity.
- The location shall ensure adequate ventilation, cooling and exhaust features,
- The room location shall ensure compliance with environmental regulations,
- The room location shall ensure easy access for refuelling operations,
- Equipment arrangement shall prioritise:
    - Provide sufficient access for operation, maintenance and removal,
    - Functional grouping of LV and emergency power supply systems,

7.5.7.2. Access and Handling (Material Shaft)

- Access provisions shall enable safe installation, removal, and replacement of heavy equipment.
- Material shafts shall:
    - Provide direct access from ground level
    - Be located to enable safe and practical logistics operations
    - Be positioned near accessible external areas where feasible

7.5.7.3. Structural and Installation Requirements

- Heavy equipment shall be installed on load-bearing concrete foundation designed for static and dynamic loads.
- Equipment mounting shall ensure:

- Mechanical stability
- Safe operational clearance
- Accessibility for switching operations

7.5.8. Compliance and Coordination

- All room layouts, equipment arrangements, and installation practices shall:
  - Conform to applicable IEC/EN standards
  - Be coordinated with project-specific design criteria and reference documents
  - Be verified with the layout drawings that will be provided for approval of the Administration.

- Additional requirements shall follow project-specific technical schedules and reference tables.

7.6. POWER SUPPLY AND TRACTION POWER SYSTEM

7.6.1. Main Power Supply and Distribution

The power supply to Istanbul Northern Ring Railway Line Project facilities will be provided;

- From the national 154kV grid, as the main power supply to the traction system,
  The contractor will provide the necessary studies to determine the required quantity of main power supply and available TEİAŞ G.I.S locations for main power supply to the system;
- From the 27,5kV busbar of the Traction Power Substation, by means of step down transformers to the Traction Power Substation facilities,
- From local MV distribution network, as the main power supply to the stations, The contractor will provide the necessary studies and to determine local M.V. substation locations for main power supply to the stations and other facilities required for system operations;
- From catenary line or local LV distribution network to the wayside technical buildings.

The above listed supplies shall be evaluated by the contractor taking into consideration the geographical location and load capacity availability of the power supply point, necessary discussions and correspondence regarding the source and method of the main power supply must be conducted with the Local Electricity Distribution Company(ies); as a result of these correspondence and discussion, the main power supply points shall be determined with the knowledge and approval of the Authority.

The design of the power supply system shall comply with, but is not limited to, the standards and regulations listed below:

- Electrical Power Installations Regulation (EKATY)
- TEİAŞ (Turkish Transmission Authority) technical specifications
- TCDD (Turkish State Railways) technical specifications
- TS EN 50119 - Railway applications. Fixed installations. Electric traction overhead contact lines
- IEC / EN 61936 - Power installations exceeding 1 kV AC
- TS EN 62271: High-Voltage Switchgear and Controlgear
- IEC 60071 - Insulation coordination
- IEC 60815 - Selection and dimensioning of high-voltage insulators intended for use in polluted conditions
- IEC 60529 – Degrees of protection provided by enclosures (IP Code)
- IEC 60076- Power transformers
- IEC 62505-3-2 - Railway applications - Fixed installations - Particular requirements for AC switchgear - Part 3-2: Measurement, control and protection devices for specific use in AC traction systems - Current transformers
- IEC 61850 - Communication networks and systems for power utility automation
- IEC 60255 - Measuring relays and protection equipment
- IEC TS 61936 - Power installations exceeding 1 kV AC and 1,5 kV DC - Part 0: Principles to be observed in the design and erection of high voltage installations - Safety of high voltage installations
- IEC 60909 - Short-Circuit Currents in Three-Phase Alternating Current Systems
- DIN VDE 0276–1000: Power Cables, Current-Carrying Capacity, General, Correction Factors
- CLC/TR 50480: Determination of Cable Cross-Sections and Selection of Protective Devices
- TS IEC 60287: Electric Cables
- TS EN 60502 - Cables – Rated voltages from 1 kV (Um = 1.2 kV) to 30 kV (Um = 36 kV)
- Regulations on Earthing in Electrical Installations

When designing the system, redundancy arrangements must be taken into account by considering power outages and various operational scenarios; the objectives of efficient and effective energy use and the minimisation of losses must also be observed.

As part of the main power supply and distribution, a single-line diagram consisting of all H.V., M.V. and traction system levels will be prepared for the entire railway line. The single-line diagram shall show all cable lengths, types, quantities and cross-sections, including input feeders; the first station inputs, HV/MV metering cells, generator centres, switchgear at all stations, traction transformers, internal service transformers, catenary, power sections (section), the length of the catenary line, switches, section posts must be specified; the technical values of circuit breakers, internal service transformers, traction transformers, generator transformers (if any) and generators, current transformers, voltage transformers, and busbars; details regarding protection and measurement elements, cell types and numbers, interlocking functions, and equipment and location codes must be provided; lines supplied from different sources must be highlighted using different line types or colours.

The power supply system design will be supported by load flow and simulation studies carried out using appropriate softwares.

The Contractor shall carry out the simulations and calculations listed below, without being limited to this purpose, in order to provide data to the above mentioned diagram and system components.

- High/Medium Voltage Simulation and Report (to be prepared using system-specific, suitable software.)
- Traction Power Simulation and Report (to be prepared using system-specific, appropriate software)
- Low Voltage System Calculation Report (to be prepared using system-specific, suitable software)
- Lighting System Simulation and Report (to be prepared using system-specific, appropriate software)
- Cable Tray System (Cable trays, ladders, etc.) Calculation Report
- Lightning Protection Calculation Report (to be prepared using system-specific, appropriate software)
- Earthing System Calculation Report
- Residual Current System Calculation Report
- Solar Energy System Design Report (to be prepared using system-specific, appropriate software)

In these studies;

- the system will be modelled and separate load flow analyses and short-circuit analyses will be carried out for normal operation, faulted operation scenarios; system components will be studied in terms of short-circuit withstand capacity, loading and voltage drop.

- For voltage drop, in accordance with Article 58-a)4) of the High-Voltage Electrical Installations Regulation, from the secondary side of the step-down transformer substations;
    - 7% limit in HV/MV normal or fault-free operation scenarios
    - 10% limit

  shall be adopted.
- All variations will be examined, including scenarios where the entire system is powered from a single main power supply point. (For example: in a railway project with two main power supply points, two different fault operation scenario variations will be simulated; in a railway project with three main power supply points, six different fault operation scenario variations will be simulated.)
- The parameters of the components in the power supply system (cables, transformers, busbars, etc.), cable correction factors based on installation type and temperature, and other input data will be fully specified in the report.
- For the load data of the Traction system, the RMS data from the normal operating scenario in the Traction power simulation report will be used.
- For stations/buildings with a design report for internal load values, the normal operating demand powers specified in the design report shall be taken into account; for existing stations/buildings without a design report, estimated demand powers shall be taken into account.
- Data from the Local Electricity Company will be used for network short-circuit powers.
- The short-circuit breaking capacities of the HV/MV switchgear busbars, the cross-sections of the HV wires/cables, MV cables, the cross-sections of the earthing conductors, the HV/MV circuit breakers, the MV current transformers and the HV/MV voltage transformers will be determined and selected; the report will set out how these selections were made, along with the details and justifications for them.
- The power values that, the system will require from the grid, will be reported separately for each operational scenario and each energy supply point.

As the Istanbul Northern Ring Railway Project railway line will be the extension/continuation of an existing railway line, the traction power transfer from the existing systems will be considered in the traction simulation studies and locating the Traction Power substations.

Depending on the structure of the railway line the auxiliary power supply to the facilities will be at individual points. Therefore, for each individual power supply point the contractor shall provide a seperate load study consisting of the above mentioned content to verify the design and to be presented to the local electric distribution authority for energy request application.

7.6.1.1. Performance Requirements

The contractor will design a power supply system to provide continuous, safe and reliable train operation along the Inrail line under operational train frequency and speed in case of the conditions stated below;

a) The system shall be designed such that, under normal operating conditions and at the normal peak-hour service frequencies, the railway system can operate continuously, and trains comprising the number of carriages specified in the testing and commissioning specification

b) In the event of the complete loss (failure) of one main power supply points as per the project, there shall be no reduction in system capacity, performance or peak-hour service frequency(ies) relative to normal operating conditions, and normal operating conditions shall be maintained.

c) Redundancy for the power supply system equipment will be provided so that, in the event of the loss (failure) of one of the two traction transformers belonging to the substation system, the system will continue to operate continuously at the operational frequency specified in the project.

d) Power supply system redundancy will be provided in all facilities for continuous operation by means of dual power sources and/or equipment in all voltage levels.

7.6.2. Traction Power Supply System

7.6.2.1. General Requirements

7.6.2.1.1. The Traction Power Supply System (TPSS) shall be designed to provide a safe, reliable, efficient and maintainable electrical power supply for all train operations under normal, degraded and emergency operating conditions.

7.6.2.1.2. The system shall support continuous railway operation for train services at design speeds of 160 km/h + %10, ensuring sufficient voltage quality, power capacity and operational flexibility.

7.6.2.1.3. The contractor will take into consideration the general practices and technical building layouts of traction power substations applied in similar railway lines in operation by TCDD (Turkish State Railways Directorate)

7.6.2.1.4. The TPSS design, equipment selection, installation and commissioning shall comply with:

a) Relevant European standards and Technical Specifications for Interoperability (TSI);

b) Applicable international standards (IEC, EN);

c) Turkish State Railways (TCDD) technical specifications, electrification standards and engineering practices;

d) National regulations and statutory requirements applicable within the Republic of Türkiye.

7.6.2.1.5. Where discrepancies exist between European standards and TCDD requirements, the Contractor shall:

a) notify the Engineer;

b) submit a deviation report;

c) adopt the more stringent requirement, subject to Engineer approval.

7.6.2.2. System Configuration

7.6.2.2.1. The traction power system shall be based on:

- Nominal voltage: 25 kV AC
- Frequency: 50 Hz

7.6.2.2.2. The system shall be configured as 1× 25 kV feeding system

7.6.2.3. Design Studies and Calculations

7.6.2.3.1. The Contractor shall carry out comprehensive system studies, including but not limited to:

a) Traction load flow analysis;

b) Voltage profile analysis;

c) Short-circuit and fault current study;

d) Regenerative braking impact analysis;

e) Harmonic distortion and power quality study;

f) Substation spacing optimisation;

g) Neutral section design and positioning;

h) Feeder and cable sizing calculations;

i) Autotransformer sizing and spacing (if applicable);

j) Contingency and degraded mode scenarios;

k) Return current and EMC compatibility analysis.

7.6.2.3.2. All calculations shall:

a) be based on approved rolling stock characteristics;

b) reflect actual timetable scenarios;

c) consider simultaneous train operations;

d) include future traffic growth scenarios.

7.6.2.3.3. The calculation methodology shall be consistent with:

- EN 50388 coordination principles;
- TCDD approved modelling practices (where applicable);
- Internationally accepted railway electrification simulation tools.

7.6.2.4. Utility Grid Connection and Interface

7.6.2.4.1. The Contractor shall coordinate with the relevant utility authority for all grid connection requirements.

7.6.2.4.2. The design shall include verification of:

a) available short-circuit power;

b) supply reliability level;

c) harmonic emission limits;

d) reactive power requirements;

e) grid disturbances and voltage stability.

7.6.2.4.3. The Contractor shall ensure compliance with:

- Turkish utility regulations;
- TCDD interface requirements for grid connection;
- protection coordination between railway and utility systems.

7.6.2.5. Traction Substations (TSS)

7.6.2.5.1. General

a) Traction Substations shall be provided at locations determined by system studies and shall ensure full operational coverage of the railway line.

b) The land dimensions of the traction substations shall be determined in accordance with the design, taking into account the building, cable trenches, drainage systems, equipment layout plans, equipment foundations, associated steel structures, busbars, feeder connections, control and protection systems, and AC-DC supply systems required for the154/25 kV traction power system.

c) 154 kV and 25 kV switchgear will be outdoor type, and the Traction Substation design shall be developed in accordance with an outdoor switchyard layout.

d) While selecting all devices that will be used in the substations, regional meteorological data (temperature, humidity, altitude, wind pressure etc.) and seismicity shall be taken into account. The determined values shall be used after approval of the Engineer.

e) In the desing of Traction Substations and selection of the materials, full compliance with the provisions of the environmental protection legislations shall be ensured. Materials harmful to the environment and human health shall not be used.

f) f) The design life of the entire system shall be at least 40 years.

7.6.2.5.2. Equipment

Each Traction Substation shall include, as a minimum:

a) 154kV High Voltage (HV) incoming switchgear (GIS);
b) 25 MVA, 154 kV/25 kV two-phase oil-immersed Traction power transformers, operating class IXB as specified in EN 50329 (2 each);
c) 25 kV feeder circuit breakers and switchgear;
d) Protection relays and control systems;
e) SCADA remote terminal units (RTU);
f) Auxiliary service transformers and distribution;
g) Battery and DC supply system;
h) Earthing grid and bonding system;
i) Fire detection and protection system;
j) HVAC and ventilation systems;
k) Lighting and auxiliary installations.

7.6.2.6. 154 kV Switchgear

7.6.2.6.1. 154 kV switchgears shall be designed as external type. The three-phase input line coming from 154 kV shall be connected to the steel construction substation entry portal. A line trap shall be established at a point to be determined between TEİAŞ branch line and substation. Line traps shall be placed on supports.

7.6.2.6.2. From the entry portal at 154 kV side, all current and voltage transformers and active and reactive meters shall comply with the EPDK (Energy Market Regulatory Authority) communication on the meters used in the electricity market and the criteria accepted by TEİAŞ.

7.6.2.6.3. Three-phase conductors coming from TEİAŞ grid shall be connected to voltage transformer that shall be connected to line disconnector. Line disconnector shall be supplied with an earthing system that is three-pole, manually/motor controlled depending on the disconnector position. The earthing system on the disconnector shall be equipped with an electromechanical interlocking system to prevent it from being closed when the disconnector is closed. The three-pole input disconnector shall be controllable when both of 154 kV transformer branch breakers are open.

7.6.2.6.4. Design Criteria

The design of Traction Substations shall:

a) comply with EN and IEC standards;
b) comply with TCDD substation design specifications and layout criteria;
c) allow safe operation and maintenance access;

d) provide redundancy where required;

e) allow future expansion where specified.

7.6.2.6.5. After input disconnector, each phase of 154 kV current transformers shall be supplied with meters and measurement systems for protection purposes. From this point, energy path shall reach 3-phase busbar. 2 two-phased branches shall be installed from two different phases of the busbar with one phase being the joint phase of both power transformers.

7.6.2.6.6. Each branch shall be supplied with double-pole and 110 VDC motor-operated disconnectors that are operatable when 154 kV transformer breaker is open. For each phase, disconnector output shall be connected to a double-pole SF6 gas circuit breaker with tripping capacity of 31.5 kA in compliance with the short circuit power in the TEİAŞ grid between the transformer disconnector and transformer. After circuit breaker, each phase shall be supplied with 154 kV current transformers for the purposes of measurement and protection. There shall be surge arresters between current transformer and power transformer.

7.6.2.6.7. 154 kV breakers to be used shall be out-door type motor-operated, spring-charged, double-pole, SF6 gas-type manually adjustable, when necessary, DC cut-protected and have coils that enable mechanical tripping when voltage is cut.

7.6.2.6.8. All breakers to be used at 154 kV side shall be locally/remotely operable. Nearby position of breakers shall not block the protection tripping of breaker.

7.6.2.6.9. In 154 kV switchgear to be installed, the entire energy transmission system shall be established with steel-core aluminium conductor having an appropriate section based on the calculations of current carrying capacity.

7.6.2.6.10. 154 kV switchgear shall provide the following basic values:

- Rated operating voltage :154 kV
- Insulator voltage :170 kV
- Impulse Resistance Voltage :750 kV
- Power frequency withstand voltage -1 minute :325 kV
- Frequency :50 Hz
- Ith short circuit current :31,5 kA
- Idyn :2,5 x Ith

7.6.2.6.11. The minimum standard clearance between external-type switchgear with rated voltage of 170 kV shall comply with the Regulation on Electric Power Installations. Phase-to-phase clearance shall be taken as 3000 mm and the height of live parts from ground shall be taken as 4000mm for 154 kV input line, busbar, disconnector and circuit breakers.

7.6.2.7. Traction Power Transformer

7.6.2.7.1. 25 MVA, 154 kV/25 kV, two-phase, oil-dipped, ONAN-type power transformers will be used at substations, together with their protection and control systems.

7.6.2.7.2. Transformers shall be designed according to IXB operating class given in EN 50329 Table A.1.

7.6.2.7.3. Transformer shall allow for on-load tap changing and tap changer shall be on the primary side. Power transformers shall have 13 taps.

7.6.2.7.4. Power transformer shall have an expansion tank, flexible separator, buchholz on oil conservator, buchholz, oil and winding temperature, oil level contact thermometer and self-protection systems for gas pressure. All equipment cables shall pass through steel spiral. Terminals of current-carrying cables inside junction box shall be double-type and these terminals shall be automatically shunted.

7.6.2.7.5. Power transformer is protected with surge arrested on both sides. Since surge arresters have a limited protection area, transformers shall remain within this area.

7.6.2.8. 25 kV Switchgear

7.6.2.8.1. 25 kV switching devices of Traction Substation shall be designed as external-type and shall operate under regional weather conditions.

7.6.2.8.2. Traction power transformer outputs shall lead to the distribution busbar of the catenary lines through 25 kV current and voltage transformers, vacuum-type and magnetically driven single-pole circuit breakers.

7.6.2.8.3. Busbar output feeders shall be supplied with motor-operated disconnectors and catenary feeder breakers, where current and voltage transformers for measurement and protection shall be provided. The feeder connection to the catenary line shall be made via motor disconnector.

7.6.2.8.4. Auxiliary service transformers shall be energised through 25 kV busbar via motor-operated disconnectors.

7.6.2.8.5. Disconnectors shall have electrical interlockings with the related feeder breakers.

7.6.2.8.6. 25 kV switchgear shall provide the following basic values:

- Rated voltage : 27,5 kV
- Insulator voltage : 52 kV
- Impulse resistance voltage : 250 kV
- Industry frequency : 50 Hz
- 1-min. withstand voltage : 95 kV
- Ith short circuit current : It will be selected in accordance with the TS EN 50388 standard.
- Idyn : 2,5 x Ith

7.6.2.9. Sectioning and Switching System

7.6.2.9.1. The line shall be divided into electrically independent sections to ensure operational flexibility and reliability.

7.6.2.9.2. The system shall include:

a) Sectioning Posts (SP);
b) Subsectioning and Paralleling Posts (SSP);
c) Neutral Sections;
d) Switching equipment (disconnectors or circuit breakers).

7.6.2.9.3. The sectioning philosophy shall:

a) minimise the impact of faults;
b) allow rapid isolation;
c) maintain service continuity;
d) support operational requirements defined by TCDD practices.

7.6.2.10. Protection and Control

7.6.2.10.1. Traction Substations shall be provided to meet the traction power demand within electrically operated zones. The Contractor shall ensure that the catenary system is continuously energised and supplied without interruption, such supply being critical to the reliability of the distribution system. The protection system shall be designed, implemented, and coordinated to ensure uninterrupted electric train operation and to minimise the duration and impact of any power outages. All such designs shall be undertaken with due diligence and in accordance with applicable standards, ensuring a high level of system reliability and operational continuity.

7.6.2.10.2. Protection systems shall be designed and implemented to eliminate, within the shortest practicable time, any temporary energy fluctuations, fault currents, or system abnormalities that may arise during normal operation, without causing damage to any part of the system. To achieve this, combined microprocessor-based devices shall be employed in both primary and secondary protection systems. Such devices shall ensure fast, selective, and reliable operation in accordance with applicable standards

7.6.2.10.3. The protection system shall include:

a) feeder protection;
b) transformer protection;
c) distance or impedance protection;
d) overcurrent and earth fault protection;
e) breaker failure protection;
f) coordination with utility protection schemes.

7.6.2.10.4. All protection relays shall generally have the following properties:

- Protection relays that will be used at 27.5 kV side shall be designed for railway applications.
- Protection relays shall have logic programming feature.
- Self-assessment function of relays shall be constantly enabled, and it shall send out a signal in case of detection of an internal failure. When the energy of relay is cut, it shall again send out signal.
- Unless otherwise specified, relays shall oscillographically store the last 5 failures in their memories and the defective phase shall be visible on the relay screen or via LED.
- The adjustments and failure loggings that have been performed shall not be erased by themselves due to cutting of auxiliary supply, running out of real time and date info batteries or other reasons.
- Even if relay is energised or under load, its values for setting shall be adjustable. Relay shall be designed in a way that it will continue protection during setting changes.
- All protection relays at the substation shall communicate with the RTU (Remote Terminal Unit) that is an upper-level system. Protection relays shall have the hardware devices required for physical connection with the upper-level system (RTU).
- The protection systems required for installation for primary and secondary circuits are specified below. The information on fuse blowing out of the voltage transformers shall be transmitted to the telecommand centre. Contractor shall submit, to the approval of Engineer, the operating principles, setting areas, economic lives, error margins, references, production validity periods and possibility of procurement from the market together with the connection diagrams of the protection plan of micro-processing devices and auxiliary systems that will be used in relation to the protection systems requested by Engineer and other systems that Contractor will offer, and Contractor shall provide the necessary description about them.
- All software and hardware, final settings and other parameters required for connection to protection relays and all programmable system devices (IED) shall be provided to Engineer.

7.6.2.10.5. Protection on 154 kV

- For protection of 154 kV switchgear between the entry portals and power transformers at the substations, there shall be definite and inverse time overcurrent protection, tripping circuit inspection, and low and high voltage protection.
- These protection systems shall receive information from the current and voltage transformers existing on every input line and placed separately for each phase. Two secondaries of the current and voltage transformers shall be used in meter and measuring circuits and one secondary shall be used in the protection circuit.
- Power quality measuring device shall be put in the meter panel.
- Characteristics such as sensitivity and class values of the current and voltage transformers are provided in the related part of the specification. This system, named as the entry protection system, shall open the 2-pole breakers at the entrance of power transformers in case of failure. To prevent 154 kV transformer circuit breaker from being opened first in case of an overcurrent or short circuit (depending on size of fault current) in the secondary, namely 27.5 kV side, of the substation, a sequential and selective protection shall be provided.

- After 154 kV input busbar (between 154 kV line feeder and power transformer), overcurrent relays shall be assigned for the overcurrent protections of the transformer feeder.
- In any event, the information on type of failure or error, the devices that operated and changed positions at the switchyard due to this event and time of the event etc. shall be simultaneously visible on the control panel and the telecommand centre.

7.6.2.10.6. Traction Power Transformer Protection

- After operation of any of the self-protections such as buchholz, gas pressure, oil level, oil temperature, winding temperature and differential, the power transformer shall open 154 kV and 27.5 kV circuit breakers at the input and output of transformer.
- Two power transformers at the same switchyard shall be protected in a way that they will not affect one another. Since the power transformer may require intervention by technical personnel after the failures in the self-protections, a locking system shall be developed to prevent servicing of the transformer without visual inspection, and this locking system shall only be resettable locally. Before the locking system is reset, the devices that change their position shall not be controllable locally or from the telecommand centre.
- Power transformers shall be equipped with a differential protection relay that will operate with reference from primary and secondary current transformers.
- Protection adjustments and coordination shall be made in a way that a sequential and selective protection will be provided by taking the transformer short circuit withstand period and 154 kV input protection values into account. In terms of adjustment areas, relays shall be chosen in line with the rated current-voltage values of power transformer.
- Contractor shall provide Engineer fully with the certificate of compliance with the related standards, information on continuity of manufacturing, ease of procurement under market conditions, references, software program and information, maintenance service guarantor information, user manuals, technical information, all external hardware of relay, cables of interconnection with other systems and scart and jack adapters of the protection relays.
- All information of power transformers and alarm, warning and operation information of protection relays shall be simultaneously traceable from the control panel and telecommand centre. To achieve this, a terminal block shall be developed for the information and position required to transmit information to the telecommand system unit.

7.6.2.10.7. Protection on 25 kV

- Phase line shall be supplied with an overcurrent relay to provide overcurrent protection for the area between the power transformer and load-disconnector transfer busbar. In order to provide overcurrent protection also from the return line, one more overcurrent protection relay shall be assigned.
- Catenary output feeders shall be switched with external-type vacuum and magnetically driven breaker. In case of a short circuit failure on its catenary line, this breaker shall be automatically opened in line with the value of the collected current. To see the current and voltage values of the catenary line, current and voltage transformers shall be installed. All information related to output feeders shall be simultaneously traceable from

the control panel and telecommand centre.

- Since most of the failures on the catenary line are temporary and the supply has to be restored in the shortest time possible for train operation, the catenary output feeder circuit breaker shall be supplied with auto-reclose. A switching mechanism shall be established to deactivate the re-closing circuit whenever requested.
- To ensure safe operation under every operating and short circuit condition, the catenary output feeder circuits shall be equipped with catenary distance protection, definite and inverse time overcurrent protection, low voltage protection, tripping circuit inspection, wrong phase coupling (WPC) protection, breaker failure protection and thermal image protection.
- One distance protection relay and one overcurrent relay shall be assigned for each catenary output feeder. These relays shall provide the protections and features specified above. The protection relays shall be specially designed for railway applications. The control circuits that will be established for the distance protection and overcurrent relays shall be separate.
- By giving priority to determination of fault currents and fixing of failure, the catenary distance protection relay shall provide a sequential and selective protection. Adjustment areas of relays shall be chosen in line with the maximum load current and voltage values that will be collected from the catenary line. The catenary distance protection relay shall be able to determine the distance between the failure and substation. This feature shall also be transmitted to the remote-control centre with all other activated features of the relay. The protection relay shall display failure notifications, time, current, voltage, distance and similar information on its own screen.
- Protection adjustments and coordination shall be provided in a way that a sequential and selective protection will be ensured by taking 154 kV input protection values, transformer short circuit withstand period and impedance values of the catenary line into account.
- Disabling of power tranformers due to a short circuit fault current occurring on the catenary line shall be prevented and the fault current shall be cleaned in the catenary output breaker.

7.6.2.11. Earthing And Return Current System

7.6.2.11.1. Earthing system that will be installed at the substation shall be calculated and designed in accordance with the Earthing Regulation and IEEEE STD 80.

7.6.2.11.2. Contractor shall develop an earthing grid after the calculations made within the related standards in line with the obtained earthing specific resistance value at the substation. The grid calculation of the earthing system shall be made and submitted to the approval of Engineer. In the calculation of the earthing grid, the inner and outer surrounding walls shall be taken into consideration and the switchyard surrounding walls and doors shall be earthed. The earthing grid shall be manufactured in a way to be 1 m outside the substation outer surrounding wall. For the earthing grid, copper conductor with a section of at least 120 mm² and copper forming steel earthing electrodes in the dimensions and quantity determined with the calculation shall be used.

7.6.2.11.3. For surge arresters, separate earthing electrodes shall be driven right next to the base of surge arrester and surge arresters shall be connected to this electrode and the earthing grid.

7.6.2.11.4. At the switchyard, there shall be a return current busbar to complete the circuits of devices such as power transformers, auxiliary service transformers, voltage transformers etc. and other systems. Since the return current busbar will be connected to rails, it will be convenient to install the busbar at the secondary side of the switchyard, near the rail. The insulated return cables coming from power transformers shall be connected with this busbar. The return cables connected to two rails of each track and the NYY cables connected to the return conductors shall be connected to the return busbar.

7.6.2.11.5. Earthing connections of all steel constructions shall be connected to the grid with proper lugs via input-output of the grid conductors and in this process, stainless steel bolts shall be used. For 154 kV side, the current-voltage transformers, surge arresters and all steel constructions shall be connected to the earthing grid from two separate points. All building and foundation reinforcements at the substation switchyard shall be connected to the earthing grid.

7.6.2.11.6. Before installation of the substation, the earthing specific resistances at the substation switchyards shall be measured. Resistance of the substation earthing systems shall be less than 0,5Ω. If the earthing resistance is not dropping below 0,5 Ω with the designed earthing conductor and electrode grid, the necessary improvement shall be made on the switchyard ground and precautions shall be taken to drop the value below 0,5Ω.

7.6.2.12. Auxiliary Power Supply for Building Services and Control Systems

7.6.2.12.1. All 230 V AC energy need of the traction substation to be designed shall be supplied from two 25/0.23 kV-30 KVA AST1-AST2 transformers (Auxiliary Service Transformers) and, if required, from the mains. To achieve this, a 230 VAC distribution panel shall be placed in the control room. There shall be a motor thermal magnetic switch inverter system inside the panel for the auxiliary service transformer 1-2 and the mains.

7.6.2.12.2. The system shall be controllable both locally and from the telecommand centre. The control phase shall energise the system after passing through every motor thermal magnetic switch. Operating status of the systems shall be viewable from the telecommand centre. Control voltage of motor thermal magnetic switches shall be 230 VAC.

7.6.2.12.3. 110 V DC supply system shall consist of a stationary battery group and the rectifier supplying this group. After the calculations required to have the supply system on full load for minimum 5 hours during energy outage, the battery and rectifier power shall be determined. The determined battery capacity shall be selected as 25% reserved. The batteries shall be lead-acid aqueous. The guarantee period shall be minimum 15 years.

7.6.2.12.4. Rectifier shall consist of modular rectifier units, control module, monitoring module, digital display screen, failure warning outputs, 230 VAC input-switch automatic fuse and sufficient number of output-switch automatic fuses for 110 VDC loads and other required units, and these units shall be inside one board/base.

7.6.2.12.5. The cabling inside the panels shall be designed in way to be easily visible and serviceable and the cable mapping system shall be complete in an understandable way.

7.6.2.12.6. Including the connections and contacts related to uninterrupted power supply hardware, Contractor shall submit all drawings and calculated plans to the approval of the Engineer.

7.6.2.13. SCADA Integration

7.6.2.13.1. The TPSS shall be fully integrated into a SCADA system for remote monitoring and control.

7.6.2.13.2. The system shall allow:

a) remote operation of switching devices;
b) real-time monitoring of voltage, current and status;
c) alarm and fault reporting;
d) event logging and analysis.

7.6.2.13.3. SCADA design shall comply with:

- project requirements;
- TCDD operational practices;
- cybersecurity requirements.

7.6.2.14. Performance Requirements

7.6.2.14.1. The Contractor shall ensure that:

a) voltage levels remain within acceptable limits under all operating conditions;
b) power supply capacity meets peak demand scenarios;
c) system availability meets contractual targets;
d) regeneration is safely handled where applicable.

7.6.2.15. Compliance with TCDD Requirements

7.6.2.15.1. All Traction Power Substation components and design shall be consistent with:

- TCDD electrification standards;
- TCDD technical specifications for high-speed railway systems;
- TCDD operational and maintenance requirements.

7.6.2.15.2. The Contractor shall:

a) review applicable TCDD standards;
b) incorporate all mandatory requirements;
c) obtain approval for any deviations.

7.6.2.15.3. Approval by the Employer and/or TCDD authority shall be required for:

a) system configuration;
b) equipment selection;
c) protection philosophy;
d) sectioning scheme;
e) SCADA integration.

7.6.3. Auxiliary Power Supply System

7.6.3.1. Scope

This section covers the medium voltage level up to 36kV of the auxiliary power supply to the railway facilities with the content of;

- MV Switchgear,
- Transforners,
- Standby Diesel Generarors
- Cables.

7.6.3.2. General

7.6.3.2.1. Auxiliary power supply system shall be designed to provide continuous and reliable power for all railway facilities and fixed installations required for operation, maintenance and safety.

7.6.3.2.2. The Contractor will determine the methods of supplying auxiliary power to the Railway facilities taking into consideration the local power supply possibilities, load characteristics of the facilities and the below listed recommendation;

- From the 27,5kV busbar of the Traction Power Substation, by means of step down transfermers to the Traction Power Substation facilities,
- From local MV distribution network, as the main power supply to the stations, the contractor will provide the necessary studies and to determine local M.V. substation locations for main power supply to the stations;
- From catenary line or local LV distribution network to the wayside technical buildings.

7.6.3.2.3. The design of the LV distribution system shall generally, but not exclusively, comply with the standards and regulations listed below:

- Regulations on Medium Voltage Electrical Installations
- TS HD 60364 series standards

7.6.3.3. Auxiliary Loads

7.6.3.3.1. Systems and facilities that require auxiliary power systems, as applicable:

a) Traction substation LV installations,
b) Wayside technical buildings LV installations,
c) Station LV installations,
d) SCADA and Communication systems,
e) Mechanical installations,
f) Battery chargers and UPS systems,
g) fire safety systems,
h) interface systems defined by the Contract.

7.6.3.3.2. Critical loads shall have suitable redundancy and backup arrangements.

7.6.3.4. Cables for Auxiliary Power Supply System

7.6.3.4.1. The desing will be in compliance with TS IEC 60502-2.

7.6.3.4.2. The cross-sections of MV cables will be determined in accordance with the results of the MV simulation detailed in the 'Main Power Supply and Distribution' section.

7.6.3.4.3. The contractor shall provide the calculation method and criterias in the Design Manual

7.6.3.4.4. In the design of MV cables, care shall be taken to meet EMC (electromagnetic compatibility) requirements, and attention shall be paid to maintaining the minimum distances from control cables and other installations.

7.6.3.4.5. Medium-voltage cables to be installed undergroun or in the tunnel structures shall be armoured. Armour for single-core cables shall be non-magnetic, whilst that for multi-core cables shall be manufactured from steel wires.

7.6.3.4.6. The distances between the supports and carriers of the MV cables will be determined based on calculations taking into account factors such as the cables' bending radii, weights, sag, and manufacturer's recommendations.

7.6.3.4.7. Underground cables to be laid from the local electricity company's transformer stations to the transformer stations where the main power inputs will be made shall be copper-conducted and shall be installed in accordance with TEDAŞ's "Regulations on the Installation (Application) Procedures and Principles for Power Cables in Electricity Distribution Networks".

7.6.3.4.8. Cable routes within the railway facility perimeters shall be designed as concrete trenches or cable galleries

7.6.3.4.9. The concrete slabs to be used in cable ducts/trenches shall be reinforced with steel. The trench route shall be incorporated into the project plans.

7.6.4. Auxiliary Power Supply for Emergency Cases

7.6.4.1. General

7.6.4.1.1. In design of the Auxiliary power supply system, the Contractor shall consider mains power outage scenarios and ensure that the following loads are supplied with backup power:

- Operationally critical system loads,
- Safety critical station loads,
- Safety critical technical building loads,

7.6.4.1.2. The type of backup power supply and the load capacity shall be determined on the basis of the facility-specific critical load list and the load calculations to be prepared and submitted for approval by the Contractor.

7.6.4.1.3. Backup capacities for battery powered systems shall be as follows:

- Power UPS batteries: 2 hours
- Signalling UPS batteries: 4 hours
- Control-communication UPS/Rectifier batteries: 3 hours

7.6.4.1.4. The above defined battery back up capacities are given for individual UPS provided for mentioned systems. İn cases where a UPS supplying combined systems, the longest backup duration of the combined loads will be considered.

7.6.4.1.5. Backup duration for standby diesel generators shall be 6 hours in full load operation.

7.6.4.2. Standby Diesel Generator

7.6.4.2.1. The Diesel generator sets shall provide continuity of electrical power supply system, within defined limits, upon failure or degradation of the commercial AC source. The sets shall supply backup to the 100% load of the fire life safety systems and operating systems in order to continue the operation of the tunnel even in case of mains failure.

7.6.4.2.2. The generator sets shall be Standby Duty rated at ekW, kVA capacities to be provided in the design documents for 400 V, 3-Phase, 50 hertz, L.V. voltage distribution systems, 1500 RPM, 0.8 power factor, including radiator fan and all parasitic loads.

7.6.4.2.3. The diesel engine shall be 1500 RPM, standby duty, fixed type, water cooled, and normal or super-charged. The engine, below 50% load, shall be able to operate without any carbon output. The engine shall be designed in order to operate at 110% of its nominal speed, without torsional vibrations and buckling and without being subject to critical speed hazards.

7.6.4.2.4. The generator shall be a synchronous, three phase, four pole, 2/3 pitch, random wound, single or double bearing, and IP23 drip proof. Bearing(s) shall be double shielded and maintenance free. The generator shall meet IEC 60034-1, NEMA MG 1 and UL1446 standards.

7.6.4.2.5. Generator shall be provided with a body mounted molded case, 3 pole 100% circuit breaker, with rating adequate for the power rating of the generator. Breaker shall utilize a solid-state trip unit. The breaker shall be of IEC construction and connected to engine/generator safety shutdowns.

7.6.4.2.6. A generator set mounted, fully solid-state, microprocessor based, control shall be provided. The control panel shall be designed and built by the manufacturer.

7.6.4.2.7. The controls shall provide the following digital readouts for the engine and generator. All readings shall be indicated in metric.

7.6.4.2.8. The diesel generator sets shall be industrial type.

7.6.4.2.9. The generator set shall be equipped with a rail-mounted, engine-driven radiator with blower fan. The cooling system shall be sized to operate at full load conditions and 400C ambient air entering the room.

7.6.4.2.10. The fuel system shall be integral with the engine. At each building where diesel generator sets shall be located, a main diesel fuel tank is provided outside the building. The generator set supplier will take required actions and provide the necessary installation to transfer the fuel to the diesel generator rooms by means of pumping where necessary.

7.6.4.2.11. The supplier shall provide an additional tank in the diesel generator rooms, if finds it necessary, meeting local codes and requirements. The tank shall meet local standards for aboveground tanks for flammable and combustible liquids.

7.6.4.3. Uninterruptible Power Supply System (UPS)

7.6.4.3.1. The Uninterruptible Power Supply System, hereinafter referred as The UPS system, shall automatically provide continuity of electrical power, within defined limits and without interruption, upon failure or degradation of the mains power.

7.6.4.3.2. Backup time duration shall be determined by the battery capacity.

7.6.4.3.3. The UPS system shall operate in conjunction with the existing three-phase power distribution system by the generator busbar. In the event of a power outage, it shall be able to supply independently clean and regulated power for critical loads.

7.6.4.3.4. The battery racks and facilities will be earthed and bonded. UPS systems will be consisted of Protecting System against DC fault.

7.6.4.3.5. The UPS shall comprise the following basic equipment:

- Rectifier / battery charger
- Inverter
- Battery bank
- Static bypass
- Manual bypass
- Monitoring by SCADA as per standards

7.6.4.3.6. Design life of UPS system shall be;

- 20 years for UPS
- 10 years for batteries

7.6.4.3.7. The UPS shall be equipped with full wave rectifiers.

7.6.4.3.8. The UPS's shall be equipped with fully electronic inverters. The inverter of one rectifier / inverter circuit shall be located in the cabinet of the respective rectifier.

7.6.4.3.9. UPS batteries shall be of the VRLA lead-acid type and shall comply with TS 1352-2 EN 60896-21/T1, TS 1352-3 EN 60896-22, TS EN IEC 62485-1, TS EN IEC 62485-2, DIN 41773, and UL94-V2. Batteries will have Eurobat standarts.

7.6.4.3.10. The factors specified in the IEEE 485 standard shall be taken into account in battery capacity calculations. For the calculation of the end-of-discharge cell voltage of the batteries: for discharge durations of up to 2 hours, 1.65 or 1.69 volts at 20 °C; for discharge durations of up to 4 hours, 1.75 or 1.76 volts at 20 °C. The battery bank calculation method will be provided based on the original battery discharge curves obtained from battery manufacturers. For each battery bank, the required number of cells, along with the nominal cell voltage and power in ampere-hours, will be specified. The load quantity to be used in the calculations will be clearly stated.

7.6.4.3.11. The design shall take into account the placement of the batteries on racks or stands. A battery cabinet may be used in low-power UPS systems. If a battery cabinet is used, it shall be forced-cooled.

7.6.4.3.12. The basic technical specifications of the UPS units to be designed are given in the table below:

Table 7.1 : UPS Technical Specifications

Input Voltage	400 V, 3-phase, 4-wire
Input Frequency	50 Hz
Input Voltage Tolerance	± 15%
Input Frequency Tolerance	±4%
Output Frequency and Tolerance	50 Hz (± 1%)
Output Voltage and Tolerances (3-phase, 4 conductors)	400 V, ±2% static & dynamic

Switchover time from inverter to bypass	< 20 ms (when not synchronised) continuous (when synchronised)
Input current harmonic distortion at full load distortion (I_{THD})	< 3%
Output voltage harmonic distortion at full load (V_{THD})	for linear loads < 3% for non-linear loads < 5%
cos Φ	Input (at rated load and rated output conditions): >0.98
Efficiency (at full load)	≥94%
Noise	≤ 65 dBA
Ambient temperature	0°C to +40°C
Optimum temperature for maximum battery life:	15–25 °C for lead-acid batteries
Humidity	Maximum 90% (non-condensing)

7.6.4.4. Loads Requiring Redundant Power Supply

7.6.4.4.1. Loads requiring redundant power supply shall be supplied from the power supply sources mentioned above in case of power outages.

Table 7.2 : Loads requiring redundant power supply

Dual-supply loads	1. Power Source	2. Power Source
Fire pump panels	Auxiliary service transformer LV main distribution board essential busbar	Standby diesel generator distribution board busbar
110V DC battery chargers	Auxiliary service transformer LV main distribution board essential busbar (to 1st battery charger)	Auxiliary service transformer LV main distribution board essential busbar (to the 2nd battery charger)
Uninterruptible power supplies (Power UPSs, Control-Communication UPSs, Signalling UPSs)	Auxiliary service transformer, LV main distribution board busbar	Standby diesel generator distribution board busbar
Tunnel lighting panels	Low-voltage main distribution board essential busbar	Main power UPS distribution panel
PLCs/RTUs belonging to the SCADA system	Auxiliary service transformer LV main distribution board busbar	Equipment supply panel for the station control room and communications room
Emergency lift (if applicable)	Auxiliary service transformer LV main distribution board busbar	Standby diesel generator distribution board busbar
Platform screen door system panel	Auxiliary service transformer LV main distribution board essential busbar	Standby diesel generator distribution board busbar
Tunnel ventilation fan panels	Auxiliary service transformer LV main distribution board busbar	Standby diesel generator distribution board busbar
Pressurisation fan panel	Auxiliary service transformer LV main distribution board busbar	Standby diesel generator distribution board busbar

Building/Station ventilation fan panel (panels for fans required to operate in the event of a fire, smoke extraction, etc.)	Auxiliary service transformer LV main distribution board essential busbar	Standby diesel generator distribution board busbar
Motor control panels (emergency)	Auxiliary service transformer LV main distribution board essential busbar	Standby diesel generator distribution board busbar
Jet fan panels (if applicable)	Auxiliary service transformer LV main distribution board essential busbar	Standby diesel generator distribution board busbar

7.6.5. Auxiliary Power Distribution System

7.6.5.1. Scope

This section covers the low voltage level of the auxiliary power distribution to the railway facilities with the content of;

- LV switchgear
- Cables

7.6.5.2. General

7.6.5.2.1. The Contractor will design an auxiliary power distribution system to supply LV power to the end users thru LV distirbution panels. Depending on the size and the load type variety of the facilities, distribution system will be designed in main and secondary distribution levels.

7.6.5.2.2. LV main distribution boards are the first (primary) boards where LV distribution is carried out on the supply side; they supply all consumers at the 400/230V AC voltage level and are directly connected to the secondary windings of internal service transformers. LV main distribution boards (including UPS main distribution boards) shall be designed in accordance with the TS EN IEC 61439-1 and TS EN IEC 61439-2 standards.

7.6.5.2.3. In LV main distribution panels, similar loads will be grouped by combining them on common busbars, and energy analysers will be fitted to these busbars. Details regarding this matter are provided in the ‘Energy Quality and Management System’ section at 6.20.

7.6.5.2.4. LV branch distribution boards are secondary system boards that supply consumers at the 400/230 V AC voltage level and are fed from the LV main distribution board. LV branch distribution boards shall be designed in accordance with the TS EN IEC 61439-1 and TS EN IEC 61439-2 standards.

7.6.5.2.5. The distribution boards will be designed to have seperate distribution busbars for loads of similar system, type, function, in cases those loads are supplied from the same distribution board.

7.6.5.2.6. The contractor will carry out load flow analyses, short-circuit analyses and voltage drop studies to determine the technical specifications and capacities of the switching devices (ACB, MCCB, MCB, etc.) and busbars to be used in the panels, using appropriate software.

7.6.5.3. Cables for Auxiliary Power Distribution System

7.6.5.3.1. The desing will be in compliance with the requirements of TS IEC 60502-1, TS HD 60364-5-52 and Regulations on the Fire Protection of Buildings.

7.6.5.3.2. The cross-sections of LV cables will be determined in accordance with the results of the LV system calculation studies with a software.

7.6.5.3.3. The contractor shall provide the calculation method and criterias for load and cable calculations in the Design Manual.

7.6.5.3.4. Cable routes within the railway facility perimeters shall be designed as concrete trenches or cable galleries.

7.6.5.3.5. The concrete slabs to be used in cable ducts/trenches shall be reinforced with steel. The trench route shall be incorporated into the project plans.

7.6.5.3.6. Cable routes in door will be designed as cable tray/ladder depending on the cable loads calculated for the subject routes.

7.6.5.3.7. LV system cables shall be halogen-free, flame-retardant, and low-smoke. Single or multi-core copper cables with 0.6 kV / 1 kV insulation shall be used in the low-voltage system. Single-core cables used for internal wiring in luminaires and panels may have a lower insulation rating. For ease of installation, cables with a cross-section of 120 mm² and above shall be designed as single core.

7.6.5.3.8. The outer sheath colour of all cables following the UPSs shall be orange. All cables extending from the UPSs to all loads (emergency lighting loads and all other critical loads) shall be fire-resistant (FE180).

7.6.5.3.9. Even if calculations of cable cross-sections indicate that a smaller cross-section would be sufficient, the minimum cable cross-sections permissible for LV cables are shown below. Cross-sections smaller than those specified shall not be used.

- Feeder cables for secondary distribution boards…….....4 mm² (minimum)
- Equipment supply panels.....….4 mm² (minimum)
- Lighting circuits……..... 2.5 mm² (minimum)
- Lighting branches..... 1.5 mm² (minimum)
- Socket circuits, branches and spurs.....2.5 mm² (minimum)
- Control cables (cables must be flexible)……..1.0 mm² (minimum)

7.6.5.3.10. The types of LV cables according to their intended use, and the maximum voltage drop (%e) limits, shall be as shown in the table below:

Table 7.3 : Types of LV feeder cables according to their application, maximum voltage drop (%e) limits

FROM		TO (Panel)	COLUMN CABLE	COLUMN CABLE < %e	LOAD	LOAD SIDE < %e
LV Main Distribution Board	Essential busbar	Escalator panel	N2XH FE 180		Escalator	5%
LV Main Distribution Panel		Conveyor belt panel (if applicable)	N2XH		Conveyor belt	5
LV Main Distribution Board		Lift power supply panel	N2XH		Lift	5
LV Main Distribution Board		Lift supply panel (if emergency is available)	N2XH FE 180		Lift	5
LV Main Distribution Board		Tunnel ventilation fan panel	N2XH FE 180		Tunnel ventilation fan, equipment (damper, etc.)	5
LV Main Distribution Panel		Jet fan panel (if applicable)	N2XH FE 180		Jet fan (if applicable)	5
LV Main Distribution Panel		Station ventilation fan panel	N2XH FE 180		Station smoke extraction & ventilation fan, equipment (damper, etc.)	5
LV Main Distribution Board		Drainage pump supply panel	N2XH		Drainage pump	5
LV Main Distribution Board		Drainage pump supply panel	N2XH FE 180		Tunnel drainage pump	5
LV Main Distribution Board		Power UPS	N2XRH FE180	1	All loads downstream of the power UPS	
LV Main Distribution Board		Control-Communication UPS	N2XRH FE180	1	All loads downstream of the Control-Communication UPS	
LV Main Distribution Board		Signalling UPS	N2XRH FE180	1	All loads downstream of the signalling UPS	
LV Main Distribution Board		110V DC battery charger	N2XRH FE180	3	Loads following the battery chargers	5
LV Main Distribution Board		Fire-fighting pump panel	N2XRH FE180		Fire-fighting pump	5
LV Main Distribution Panel		Jockey pump panel	N2XH		Jockey pump	5
LV Main Distribution Panel		Pressurisation fan panel (if applicable)	N2XRH FE180		Pressurisation fans for emergency exit stairwells and lift shafts	5
LV Main Distribution Board		Power quality and management system panel	N2XH	2	Power quality and management system hardware	
LV Main Distribution Panel		Outdoor switchgear heater sub-distribution panel	N2XRH	3	(if applicable) for open-air switches on viaducts, expansion joints and sections where the gradient exceeds 4% in open areas	5

FROM		TO (Panel)	COLUMN CABLE	COLUMN CABLE < %e	LOAD	LOAD SIDE < %e
LV Main Distribution Panel		Platform screen door system panel (if applicable)	N2XRH FE180		Platform screen door system	5
LV Main Distribution Panel	Non-essential busbar	Motor control panels (MCC)	N2XH		Ventilation fans and equipment (dampers, etc.) for staff/technical areas excluding passenger areas, as well as mechanical equipment such as water pumps, heaters, air conditioning units, water heaters, etc., and spiral roller shutters at station entrances	5
LV Main Distribution Board		Tunnel sockets panel	N2XRH	2		5
LV Main Distribution Board		Station lighting and socket panel (standard)	N2XH	3	Station mains luminaires	4
LV Main Distribution Board		Station lighting and socket panel (standard)	N2XH	3	Station mains sockets, suspended ceiling circuit breaker distribution boxes, loads specified in the “Auxiliary Loads” table, hand dryers, etc.	5
LV Main Distribution Board		Wastewater pump supply panel	N2XH		Wastewater pumps	5
Power UPS		Main Power UPS Distribution Panel	N2XRH FE180	1.5	Loads specified in the relevant sections of the table	
Control-Communication UPS		Station control room and communications room equipment supply panel	N2XRH FE180	2	All hardware relating to CCTV, public address systems, fare collection, fire detection and alarm systems, etc., as well as the UPS sockets in the station control room and the communications room	3
Signalling UPS		Signalling room equipment power supply panel	N2XRH FE180	2	Signalling system hardware (signalling cabinets, point motors, etc.) connected to the UPS sockets in the signalling room	3
Main Power UPS Distribution Panel		Tunnel emergency lighting panel	N2XRH FE180	3	Tunnel emergency luminaires	5
Main Power UPS Distribution Panel		Station lighting and socket panel (emergency)	N2XRH FE180	2.5	Station emergency luminaires, UPS sockets for office-like areas where applicable	5
Main Power UPS Distribution Panel		Motor control panels (emergency)	N2XRH FE180		if present, fire curtains/doors, etc.	5

FROM		TO (Panel)	COLUMN CABLE	COLUMN CABLE < %e	LOAD	LOAD SIDE < %e
Main Power UPS Distribution Panel		Emergency control panels	N2XRH FE180	2.5	Station signs (normal exit, emergency exit, emergency escape direction signs, illuminated emergency (“danger – do not enter”) signs)	5

7.6.5.4. Installation of Low-Voltage Power Cables

7.6.5.4.1. Turkish standards and IEC standards shall apply cable installation in railway facilities.

7.6.5.4.2. Cables on the wayside and in the tunnels shall be installed in concrete cable ducts, installed beneath the walkways located on either side of the main line or in cable trays to be installed on the walkway side of the tunnels taking into consideration the dynamic envelope in the tunnel structure design. These ducts shall be used for low-voltage power distribution, communication, signalling and control cables.

7.6.5.4.3. Power and communication cables passing from the cable duct to passenger stations within tunnels will be placed inside HDPE pipes embedded in reinforced concrete.

7.6.5.4.4. In the buildings/stations, cables will be routed through cable ducts (cable trays, cable ladders) secured to the wall/ceilings of the technical areas, undersides of platforms, ceilings of the room’s electrical shafts, or the ceilings and walls of the structure using suspension/support elements.

7.6.5.4.5. The Contractor shall design, coordinate and implement the cable installation arrangements at building–wayside and building–tunnel interface zones, ensuring full compatibility and integration with all related systems and structures."

7.6.5.4.6. The cable installation in passenger areas shall be designed to be concealed.

7.6.5.4.7. The redundant supply circuits for a single load shall be routed via separate paths. Where this is not feasible along the entire route or a section thereof, measures shall be taken to protect cables on shared conduits, ducts, etc., against fire. The fire protection duration shall be at least 3 hours. In addition, where two cables are located at very close distances to one another, all necessary measures shall be taken to prevent one dual-cable supply from causing damage to the other relevant cable supply. Insulation shall be provided using fire-retardant material at room junctions.

7.6.5.4.8. Loads requiring redundant supply shall be supplied via cables with copper conductors, low smoke density, halogen-free, non-corrosive, fire-resistant (FE180), and flame-retardant. These loads shall include interlocking and control equipment to ensure that the power sources do not overlap and that automatic transfer to the other source is provided should one source be lost.

7.6.5.5. Cable Carrying System

7.6.5.5.1. Cable trays and ladders shall be of heavy-duty type with hot-dip galvanised coating. Where cables for power, lighting, fire alarm, earthing and communication-control systems are present, they shall be routed through cable trays within the suspended ceiling. In projects, a 20% reserve space shall be provided for cable trays based on the calculated tray dimensions.

7.6.5.5.2. In cable shafts, cable ladders shall be used for the vertical routing of MV cables and LV cables. Where cable trays are not used between the cable trays and the final destination of the cables, the cables shall be pulled through steel conduit. No more than four galvanised steel pipes shall be installed side by side. Where more than four cables are used, a cable tray shall be installed.

7.6.5.5.3. In cable tray capacity calculations, it is assumed that power distribution cables, lighting cables and socket circuits will be laid side-by-side in a single row within the tray. A cable tray calculation report will be prepared to determine the capacities of cable trays and ladders, taking into account reserve space.

7.6.5.5.4. The dimensions of the cable trays/ladders shall be as specified below:

Table 7.4 : Cable tray/ladder dimensions

Width (mm)	Side Height (mm)	Sheet Thickness (mm)
50–100	40	1
200	40	1.5
300	40	1.5 – 2
400–500–600	40	2

7.6.6. SCADA, Control And Remote Supervision

7.6.6.1. General

The Contractor shall design a SCADA-compatible system for remote monitoring and control of the overall power supply and associated fixed installations.

7.6.6.2. Functional Requirements

7.6.6.2.1. The SCADA-related solution shall include, as a minimum:

a) remote command of switching devices;
b) remote indication and status monitoring;
c) analog measurements;
d) alarm handling;
e) event and disturbance recording;
f) sequence of events logging;
g) energy metering and trending;
h) local/remote control interlocking;
i) secure communication interfaces.

7.6.6.2.2. The contractor shall provide a list for controlled, monitored systems, equipment and data required from the overall systems of Railway.

7.6.6.3. Interface Requirements

The Contractor shall define and implement all required interfaces with the control center, substations, sectioning posts, metering systems and other systems identified in the interface matrix.

7.6.7. Electromagnetic Compatibility (EMC)

7.6.7.1. General

7.6.7.1.1. The complete system shall be designed to ensure compatibility with signalling, telecommunications, rolling stock and third-party electrical infrastructure.

7.6.7.2. EMC Studies

7.6.7.2.1. The Contractor shall perform and submit:

a) overall EMC study;
b) induced voltage and coupling study;
c) harmonics and power quality study;
d) return current compatibility study;
e) interface assessment with signalling systems.

7.6.8. Lightning Protection and Surge Protection

7.6.8.1. General

7.6.8.1.1. The Contractor shall provide suitable protection against direct lightning strikes, induced overvoltages and switching surges.

7.6.8.1.2. All surge protection devices shall be coordinated with the system insulation design and earthing philosophy.

7.6.9. Tunnel, Bridge And Station Interfaces

7.6.9.1. Tunnel Interfaces

7.6.9.1.1. The Contractor shall coordinate with the tunnel design to ensure compliance with:

a) structural clearances;
b) fixing arrangements;
c) emergency walkway clearances;
d) fire and life safety strategy;
e) maintenance access provisions;
f) ventilation and smoke extraction interfaces.

7.6.9.2. Bridges and Viaducts

7.6.9.2.1. The Contractor shall account for structural movements, expansion joints, wind effects and electrical continuity across bridges and viaducts.

7.6.9.3. Stations

7.6.9.3.1. At station areas, the Contractor shall address:

a) platform clearances;
b) canopy and roof interfaces;
c) passenger safety;
d) lighting coordination;
e) architectural restrictions;
f) sectioning and operational flexibility.

7.6.10. Fire Safety and Tunnel Requirements

Where the line includes tunnels, underground boxes or enclosed technical spaces, the Contractor shall comply with the applicable project fire strategy and shall address:

a) low flame spread cable selection;
b) smoke and toxicity criteria where required;
c) fail-safe isolation arrangements;
d) emergency power philosophy;
e) access for emergency services;
f) electrical segregation of essential systems.

7.6.11. Design Deliverables

7.6.11.1.1. The Contractor shall submit, at minimum:

a) Electrical Systems Design Manual;
b) System Descriptions for the Electrical Systems scope of works;
c) Traction Power Studies;
d) HV and MV Load Flow Studies
e) EMC studies;
f) Earthing And Bonding Report;
g) Overall System Single Line Diagram,
h) Substation, Station, Wayside Technical Buildings Electrical System Design Reports and drawings;
i) Interface Matrix
j) Technical Specifications of the designed system for procurement and construction phase
k) All as-build drawing related to the Power Supply Systems.

7.6.12. Small Power Distribution

7.6.12.1. Socket Outlet Installation

7.6.12.1.1. General

- No more than 6 sockets shall be connected to each circuit. Furthermore, in load calculations, it shall be assumed that only one of the sockets on each circuit is in operation.
- Residual current circuit breakers (RCBOs) with overcurrent protection will be used on all socket circuits; the residual current rating will be 30 mA.
- Minimum cable size for the socket feeder lines will be 2,5mm2.

7.6.12.1.2. Socket outlets in Public Areas:

- 230 V sockets shall be positioned at intervals of no more than 30 metres in passenger areas; and at intervals of no more than 20 metres in common areas such as technical corridors, staff corridors, etc., outside passenger areas.
- A total of two 32A, 5-pin flush-mounted three-phase sockets will be installed on the platform levels, with one in the centre of each platform.
- Power distribution systems will be installed at each passenger station for the equipment detailed in the table below. Circuit breaker distribution boxes will be designed on-site at an appropriate height, depending on the location and number of these loads, for information panels, passenger information screens (info screens), X-ray detection devices, charging stations for mobility aids, food and beverage vending machines, bank ATMs, and kiosks (touchscreen information terminals). These fuse distribution boxes will be powered from the socket busbars in the lighting and socket panels.

Table 7.5 : Socket supply for loads in the facility public areas

	Type of Load	Function of the Load	Supply Method	Location	Quantity	Comments
1	Ticket machine	…top up cards, issue a single-use ticket, … sell cards	UPS+ data	Ticket hall floor in the uncontrolled area	At least 3 units per turnstile zone	Power will be supplied via the communication UPS from the fare collection panels.
2	Information Panel	To inform passengers about timetables, route maps, etc.	Mains + data	In the passenger entrance areas on the passenger entrance level	As many as there are entrances	The data line will be used for the digital information board.
				On the ticket hall floor	1 or 2 depending on the size of the area	

	Type of Load	Function of the Load	Supply Method	Location	Quantity	Comments
					1 digital information display	
				On the platform level	6 units in total: 3 units for the first platform and 3 units for the second platform 1 digital information display *May be reduced if the platform length is 90 metres or less.	
3	Food and beverage vending machines	To supply passengers with food, soft drinks, water, coffee, tea, etc.	Network	To be decided on-site by the operating company at the passenger entrance level	To be decided by the on-site operator	Distribution boxes will be installed at intervals of 50 metres at a suitable height on the platform, and these boxes will be sized to supply four vending machines. Additionally, Distribution boxes will be installed around the escalators on island platforms and in the passageways between platforms on other types of platforms.
				On the ticket hall level, the decision will be made on-site by the operator within the controlled area	Decisions will be made on-site by the operator	
4	Bank ATMs	For passengers to carry out banking transactions	Network + data +phone	Decisions regarding uncontrolled areas will be made on-site by the operator	5 units at each proposed location	
5	Payphone	To meet passengers' communication needs	UPS + telephone	In the ticket hall, the decision regarding the	2 units at each proposed location	Power will be supplied by a communication UPS.

	Type of Load	Function of the Load	Supply Method	Location	Quantity	Comments
				uncontrolled area will be made by the operator on-site	(1 accessible + 1 standard)	
6	Kiosks (Touchscreen Information Terminals)	To meet passengers' communication needs	Network	Decisions will be made on-site by the operator within the controlled area	Decisions will be made on-site by the operator	
7	Charging Stations for Mobility Scooters	To meet the charging needs of electric wheelchairs used by passengers with disabilities	Mains	The decision regarding the turnstile area (uncontrolled zone) will be made by the operator.	The operator will decide on-site.	
8	X-ray Detector Devices	To ensure the safety of passengers and their belongings.	UPS	Turnstile area within a controlled zone.	At least 1 unit per turnstile area (may increase depending on passenger volume)	Power supply will be provided by the communication UPS.

7.6.12.1.3. Socket outlets in Office/Technical Areas:

- In areas such as staff and technical rooms, at least one 230V socket shall be installed if the room area is less than 10 m², and at least two if it is greater than 10 m². Depending on the intended use of the room, a greater number of 230V sockets may be installed. In office areas, the layout shall be designed according to the furnishings and requirements.
- In large technical rooms such as medium-voltage equipment rooms, fire pump rooms, station general ventilation rooms and tunnel ventilation fan rooms, at least one combined socket box shall be installed. The combined socket boxes to be installed in these rooms shall be corrosion-resistant, halogen-free, high-strength, and shall contain one 16 A single-phase 3-pin socket and one 32 A three-phase 5-pin socket. In addition to the output MCBs, the combined socket box will incorporate a 4x40A, 30mA residual current device (RCBO) with overcurrent protection at the input.
- In staff rooms intended for office use where flush-mounted installation is not feasible, socket installations will be carried out using flexible, halogen-free cable ducts. The height of these ducts will be 20 cm from the finished floor level.

- Power distribution systems will be installed at each passenger station for the equipment detailed in the table below. These fuse distribution boxes will be powered from the socket busbars of the lighting and socket panels.

Table 7.6 : Socket supply for loads in the facility technical areas

	Type of Load	Function of the Load	Supply Method	Location	Quantity	Comments
1	GSM base stations	To meet passengers' communication needs	Network	A room of at least 20 m² in size, located on a floor close to ground level and near shafts leading to the surface, will be allocated for 3 GSM base stations	1 unit	Power supply will be provided by GSM operators via the local electricity distribution company. In cases where power cannot be supplied from the local electricity distribution company via the , power may be supplied from the mandatory busbar of the LV main distribution board with the approval of the Authority/Building Inspector.
2	PDKS	Staff attendance control system	UPS+data	SOR Zone	1 unit	Power supply will be provided by the communication UPS.

7.6.12.1.4. Socket outlets in Station Control Rooms:

- At least 10 mains sockets will be installed in the station control rooms. In addition, a minimum of 4 floor-mounted junction boxes must be installed for the UPS and mains sockets located within the room.

7.6.12.1.5. Socket outlets in Traffic Control Center (if any):

- Each session (e.g. SCADA session, vehicle session, etc.) will draw its power from UPS sockets.
- UPS sockets will be distributed evenly across the phases for each session.
- At least 3 mains sockets will be installed for each session.
- A sufficient number of sockets will also be positioned in the installation areas behind the panel screens.
- At least 10 mains sockets will be installed in the station control rooms. In addition, a minimum of 4 floor-mounted junction boxes must be installed for the UPS and mains sockets located within the room.

7.6.12.2. Tunnel Socket Distribution

7.6.12.2.1. Tunnel socket boxes will be positioned at 250-metre intervals along the railway tunnels and at the start and end points of the tunnel wall for each track. In areas where switches are located, socket boxes will be positioned every switch motor zone. Tunnel socket boxes will be installed on the side where the walkways are located.

7.6.12.2.2. 400 V LV feeder lines will run along each track, originating from a tunnel socket panel and supplying power up to the tunnel socket box at the mid-point of the next station. The remaining half of the tunnel socket boxes beyond this point will be supplied from the tunnel socket panel belonging to the next station.

7.6.12.2.3. The tunnel socket boxes for each track will be supplied from separate lines. In the calculation of tunnel power lines, it will be assumed that the socket box at the end of the line is used. In panel power calculations, it will be assumed that only one three-phase socket in a single socket box per half-tunnel between supply centres will be used.

7.6.12.2.4. A residual current protection relay with a 300 mA threshold will be installed on each tunnel/viaduct power supply line. Tunnel power distribution boards will be installed on the railway/platform level of the facility supplying power to the outlet boxes. The panels will be positioned either within any existing panel rooms in this area, or, if none exist, in the location best suited to operational requirements (e.g. not obstructing staff access, providing sufficient maintenance space, etc.). One tunnel socket panel will be installed for two tracks of the railway for every subject section.

7.6.12.2.5. To protect against the effects of water seepage from the tunnel wall, installation will be carried out ensuring an appropriate clearance between the tunnel socket boxes and conduits and the tunnel wall.

7.6.12.2.6. Each tunnel socket box shall have the following characteristics:

- IP65 protection class, corrosion-resistant, halogen-free, high-strength,
- 3-phase, 4-pole (3P+N) input, with a 30 mA 40 A residual current circuit breaker (RCBO)
- At the output, a 16 A single-phase MCB-protected, 3-pin, 1-socket outlet with a 180° opening recessed hinged cover
- Output: 32 A three-phase MCB-protected, 180° opening recessed hinged cover, 5-pin single socket

7.6.13. Lighting System

This section sets out the design criteria to be applied in the lighting design of railway lines.

7.6.13.1. Lighting Design in Railway Facilities

7.6.13.1.1. Lighting systems shall be designed in accordance with relevant national and international standards and regulations.

7.6.13.1.2. Lighting designs shall be simple, safe, efficient and facilitate practical maintenance; they shall be in accordance with architectural projects, taking into account the illuminance levels specified in international standards and planning luminaire placements that maximise their effectiveness.

7.6.13.1.3. The design principles for the lighting system shall be applied as listed below:

- Power for the lighting system will be supplied from both the mains and the UPS.
- When selecting lighting luminaires, the functions of the areas and the architectural structures will be taken into account, and the most suitable luminaire type will be chosen.
- When positioning the lighting fixtures, the suspended ceiling heights specified in the architectural plans will be used as a basis. In areas without suspended ceilings, heights appropriate to the installation level will be taken into account.
- To ensure lighting quality and comfort, attention will be paid to the uniformity of the lighting level, eye adaptation, glare factor and colour temperatures.
- Lighting levels throughout the station will generally be uniform; however, higher illuminance levels will be provided above ticket vending machines and fare collection devices, along platform edges (on the yellow line), and on and in front of staircases.
- Lighting fixtures will be positioned in such a way as to facilitate easy maintenance; locations that are difficult to access or at a height will be avoided.
- When selecting luminaires, care will be taken to ensure they are readily available and selected to require the minimum number of spares.
- Lighting fixtures above the yellow line shall be designed to be positioned at least 50 cm inside the platform boundary for ease of maintenance/safety and light output. In the case of PSDS, this distance shall be calculated separately.
- To promote energy efficiency and staff motivation, skylights should be incorporated into the design of stations, workshops and office spaces, taking into account architectural and lighting engineering considerations, to maximise the use of natural daylight. Similarly, as an alternative application, daylight tubes—a natural lighting system—may also be utilised. In areas where these applications are implemented, the installation must be designed and controllable in such a way as to utilise natural light during daytime hours to achieve energy savings.
- The positions of lighting switches will be determined according to door directions and designed to ensure ease of access.
- The cable cross-section for all lighting circuits shall be at least 1.5 mm^2
- In large-volume areas (passenger areas, etc.), the lighting installation shall be carried out using three-phase circuits.

- The L1, L2 and L3 phases shall be distributed homogeneously and symmetrically both within each lighting circuit and across the entire area where the installation is to be carried out; adjacent luminaires shall not be supplied from the same phase.
- The layout of lighting fixtures in equipment rooms shall be designed to illuminate staff work areas without casting shadows. The lighting arrangement shall be compatible with the equipment layout.
- Outdoor lighting shall be designed taking into account emergency lighting, pedestrian and vehicle traffic, and the lighting on surrounding roads shall also be taken into consideration.
- Residual current operated circuit breakers (RCBOs) with a 30mA residual current threshold and overcurrent protection shall be installed on all lighting circuits.
- In accordance with the Regulation on the Fire Protection of Buildings, for railway lines located in seismic zones 1 and 2, battery-powered emergency lighting fixtures capable of operating independently for at least 2 hours in the event of a power failure shall be used in the lighting systems of emergency escape corridors and emergency exit staircases.
- All signs located in stations (standard exit signs, emergency exit signs, emergency escape direction signs, and illuminated emergency (“danger—do not enter”) signs) must be connected to an emergency power supply and fitted with LED lighting. All signs other than illuminated emergency (“danger – do not enter”) signs shall operate on a 24-hour basis, be always illuminated and shall not be manually switchable.
- All areas monitored by cameras shall be adequately lit.
- Integrated lighting will be provided, including the illumination of vertical surfaces for advertising and the illumination of architectural details.

7.6.13.2. Lighting Levels

7.6.13.2.1. The lighting system shall be designed to meet the requirements of the railway system wide facility areas. Luminaire selections shall be made according to the function of the areas, its furnishings, decorative concept, and the characteristics of the materials used. Taking into account the characteristics of the selected luminaires, the necessary lighting calculations shall be performed using appropriate software, and projects shall be developed based on the data obtained. The main criteria to be applied in lighting design are specified in the table below.

Table 7.7 : Lighting design criteria

Calculation Criterion	Required Value
Maintenance factor	≤ 0.8
Uniformity level in public areas under normal lighting (E_{min}/ E_{avg})	≥ 0.5
Uniformity level in emergency lighting (E_{min}/ E_{avg})	≥ 0.2

Glare index in public areas	< 22

7.6.13.2.2. In addition, the reflectance factors of the ceiling, wall and floor surfaces specified in the architectural plans for the relevant area shall be taken into account.

7.6.13.2.3. Based on the TS EN 12464-1 standard, the required lighting levels to be provided by maintained luminaires are given in the table below.

Table 7.8 : Station illuminance levels

Area	Average Illuminance E_m(lux)	Measurement Position
Passenger Areas:		
Platform (underground)	200	Floor
Platform edge on the yellow line (underground)	250	Floor
Platform (at grade)	50	Floor
Platform edge on the yellow line (at grade)	100	Floor
Connecting passages and tunnels (on the platform, etc.)	150	Floor
Concourse (general)	200	Floor
Turnstiles and machines (ticket machines)	300	Counter height
Elevator entrances (inside and outside the station)	200	Floor
Escalators and stairs	200	Steps
The lower and upper sections of escalators and stairs	300	Floor
Stairs leading to the street	200	Step (street level)
General toilets	150	Floor
Outdoor parking areas	75	Road surface
Pedestrian areas, access routes/areas to station entrance structures, and, where applicable, entrances to ground-level technical structures and emergency exit staircases	75	Road surface
Staff facilities and building areas:		
Office areas	300	Desk height
Staff rooms	200	Floor

Area	Average Illuminance E_m(lux)	Measurement Position
Changing rooms	150	Floor
Staff and technical area corridors	125	Floor
Staff toilets	150	Floor
Storage rooms	125	Floor
Station control rooms	300	Desk height
Surface of equipment panels/cabinets	250	Perpendicular to the panel/cabinet surface, centre of the panel 600 mm above the floor
MV-LV equipment rooms	250	Floor
Panel and equipment rooms	200	Floor
Under the platform	50	Floor
Various (electrical, mechanical, etc.) shafts	20	Walls
Drainage and sewage pump pits	50	Walls
Lift shafts/wells	50	Walls
Emergency escape staircases (if any)	150	Steps
Tunnels/Viaducts:		
When all lighting fixtures are in operation	10	On the walkway surface (avg.)
	5	On the walkway surface (min.)
Emergency lighting	1	On the walkway surface (min.)
In the switch areas (on the switch blade)	100	Horizontal plane at top of rail
Tunnel connection (cross passage, CP) areas	20	Floor
Viaducts	10	On the walkway surface (avg.)
Entrances from the open air into the tunnel (daytime)	200	Horizontal plane at track level

7.6.13.3. Control and Operation of the Lighting System

7.6.13.3.1. Public area's normal lighting and emergency lighting circuits will be controllable separately from the SCADA system and the associated control panel. For this reason, contactors will be installed on the lighting circuits of the lighting and socket panels. All lighting control circuits controlled via SCADA will be configured to ensure that lamps connected to a control relay remain energised even if the power to that relay is cut off, and will be designed based on a fail-safe principle to protect against faults. The control of normal lighting in public areas will be carried out automatically via a time schedule from SCADA.

7.6.13.3.2. Emergency lighting in public areas shall operate on a 24-hour basis; where underground areas exist, manual switching on/off via a switch on-site shall not be permitted. For at-grade stations, emergency lighting shall be implemented during hours of darkness and shall be controlled via 'automatic' and 'manual' modes, with 'day' and 'night' settings.

7.6.13.3.3. Platform exits (the area between the end of the passenger area and the start of the track), general toilets, offices, technical areas and all partitioned rooms/areas shall be controlled by switches (standard, toggle, rocker, push-button, etc.) installed in accordance with the specific requirements and purpose.

7.6.13.3.4. Staff and technical area corridors, emergency exit staircases (if any), and passenger and staff toilets will be controlled by motion sensors.

7.6.13.3.5. External lighting will be controlled by astronomical time relays.

7.6.13.3.6. In tunnels lighting system will be provided with manual on/off switches installed on the start and end walls of the tunnels and at every 250 meters along the tunnels. In addition, the circuits will be switched on and off automatically via the SCADA system. When designing the track-side lighting system, to ensure safe access to the track from the entrances for lighting safety purposes, the line of the relevant track may only be activated or deactivated by an authorised person. If the lighting has been activated via SCADA, it will not be possible to intervene with the lighting from the site. If the lighting is activated from the site using buttons located in each CP (cross passage) area along the relevant line, it will only be deactivated by the authorised person; SCADA will not be able to intervene.

7.6.13.3.7. Tunnel lighting system will also be activated by an interface with signalling system, during the train passages.

7.6.13.3.8. Viaduct lighting control will be controlled by astronomical time relays.

7.6.13.4. Emergency Lighting

7.6.13.4.1. Emergency signs/signboards and emergency directional luminaires shall be installed in accordance with relevant standards and published specifications, in the appropriate numbers, to ensure people can be safely directed to exits, in the event of a power outage or an emergency.

7.6.13.4.2. All emergency lighting fixtures shall be powered by the UPS.

7.6.13.4.3. The ratio of emergency luminaires to the total number of luminaires in the relevant area shall be applied as per Table 7.9.

Table 7.9 : Minimum emergency lighting fixture ratio

Definitions of Areas to be Lit	**Minimum Emergency Lighting Fixture Ratio**
Passenger areas, offices, staff rooms/facilities, staff and technical area corridors	25
MV-LV equipment rooms, switchboard and equipment rooms, lift shafts, various (electrical, mechanical, etc.) shafts and ducts, station control rooms, under-platform areas, emergency escape staircases	50
Tunnels, viaducts	50
Fire protection systems (fire pump rooms, (if applicable) gas extinguishing rooms)	75

7.6.13.5. Tunnel and Viaduct Lighting

7.6.13.5.1. Lighting will be provided in tunnels and viaducts longer than 400m.

7.6.13.5.2. Lighting levels will be in compliance with the values defined on the tables given above.

7.6.13.5.3. Lighting will be designed to be provided from a single tunnel wall on the walkway side. The track-side lighting system will be powered by two sources: the mains supply and a UPS. If the active source (mains or UPS) fails (i.e. loss of mains or UPS input voltage), the inactive source will automatically take over. When the lost source is restored, the system will automatically revert to its previous state.

7.6.13.5.4. Three phase busbar system will be provided to supply the lighting system, which will be in compliance with IEC 61439-6, with following features;

- Each busbar element shall be provided with a thermal label on its enclosure indicating the surface temperature value,

- The enclosure construction shall not be bolted type and designed as non-removable / non-openable, ensuring mechanical integrity and safety,
- All insulating materials shall be Halogen-Free, flame-retardant (V0), and non-flame propagating,
- The system shall have a protection rating of at least IP55,
- If busbar lines pass through expansion points, a 3-axis expansion (dilatation) element must be used at the transition point,
- The nominal insulation voltage of the busbar system shall be 1000 V,
- The busbar system shall be manufactured as a 4-conductor system in a 3P + N phase configuration and shall use copper conductors of same cross section for P and N conductors,
- The enclosure of the busbar system shall be used as the grounding conductor.

7.6.13.5.5. The tunnel normal and emergency lighting circuits will supply half length of a tunnel section between two auxiliary power supply substations from both ends.

7.6.13.5.6. A tunnel normal & emergency lighting panel will supply all tunnel emergency and normal luminaires up to the halfway point of all tracks on the side where it is located. The luminaires for each track will be supplied from separate circuits. Residual current circuit breakers (RCBOs) with overcurrent protection will be used on each tunnel lighting circuit, with a residual current rating of 30 mA. IP65-rated, corrosion-resistant, halogen-free, high-strength cable glands will be used for connections from the tunnel lighting circuits to each tunnel luminaire. Care will be taken to ensure that all cable glands are at the same level and properly aligned. The cable glands will be installed in a manner that allows for easy access and maintenance.

7.6.13.5.7. Tunnel lighting luminaires shall be positioned at a height that allows a technician of average height standing on the walkway to replace the lamps without the use of a ladder or other equipment.

7.6.13.5.8. Tunnel normal & emergency lighting panels shall be installed on the platform levels; in the areas between the end of the passenger area and the start of the tunnel. Within this area, the panels shall be installed either in panel rooms, if available, or in the location most suitable for operational requirements (e.g. not obstructing staff access, providing sufficient maintenance space, etc.).

7.6.13.5.9. The tunnel lighting design shall ensure that, should power to the catenary be interrupted in any section, all tunnel lighting luminaires in the relevant section will illuminate regardless of the manual or automatic lighting control. All tunnel lighting control circuits here shall be arranged on a fail-safe basis, such that the lamps connected to a control relay remain energised even if the power to that control relay is cut off.

7.6.13.5.10. Permanent lighting shall be provided in the tunnel area for tunnel connection areas (cross passages (CP)), emergency escape staircases (if any), switch regions (switch tongue) and fire panels (fire cabinets) shall be provided with permanent lighting in accordance with the details specified below.

7.6.13.6. CP Areas

7.6.13.6.1. Blue-light lamps shall be used at the entrances to CP zones (where they join the main tunnel lanes), and these lamps shall be powered directly from the tunnel lighting panel's UPS busbar, independently of the tunnel lighting system. These lamps shall not be capable of being switched off by SCADA under any circumstances and shall remain illuminated at all times. Within the CP zones, standard tunnel lighting lamps will be used and connected to the nearest tunnel lighting circuit.

7.6.13.6.2. Blue-light lamps will also be used at locations where emergency telephones are situated outside the CP zones, and these will be installed in accordance with the installation details and scope provided in the preceding paragraph.

7.6.13.7. Tunnel Emergency Escape Stairways

They will be directly powered independently of the tunnel lighting via two separate UPS lines connected to the lighting panels of two adjacent stations. The luminaires in the structure will be controlled by 180-degree motion sensors.

7.6.13.8. Switching Sections

The tunnel lighting will be supplied directly from the UPS busbar of the tunnel lighting panel, independent of the tunnel lighting system. These lights cannot be switched off in any way via SCADA and will remain on continuously. LED projectors will be used. The lighting in these areas will ensure that the switch point is clearly visible, with the aim of enhancing the driver's perception.

7.6.13.9. Fire Panels (Fire Cabinets)

The tunnel lighting panel will be powered directly from the UPS busbar, independent of the tunnel lighting system. The lights indicating these panels will be red. These lights cannot be switched off by the SCADA system in any way and will remain lit at all times. This will ensure that these critical equipment areas are clearly visible to staff.

7.6.14. Outdoor Lighting

The scope and details of the outdoor lighting are set out in the subheadings below. All external lighting will be controlled by astronomical relays. All external lighting fixtures will have an IP 66 protection rating and will be selected to suit the environmental conditions.

7.6.14.1. Station Entrance Structures Lighting

7.6.14.1.1. Station entrance structure lighting;

Two separate lighting circuits will be designed, one UPS-powered and the other mains-powered. The proportion of UPS-powered luminaires will be at least 25%. LED projectors will be used.

7.6.14.1.2. Totem interior lighting;

The station entrance structure will be powered by the mains lighting circuit. Totems will have a minimum IP66 protection rating, and each totem will have an access panel for fault intervention.

7.6.14.1.3. Technical structures with ground-level entrances and emergency exit staircases;

Where such structures exist, the entrance areas will be illuminated and powered by the UPS circuit. LED floodlights will be used.

7.6.14.1.4. Illumination of the area in front of lifts for disabled access;
The station entrance structure will be powered by the UPS lighting circuit.

7.6.15. Fixture Types

7.6.15.1.1. LED luminaires will be used for the station and all other structures. Additionally, ambient lighting using RGB LEDs may also be provided in these areas.

7.6.15.1.2. Lighting luminaires will be designed in accordance with TS EN 60598 standards.

7.6.15.1.3. The colour temperature of all lighting luminaires will be 4000 K.

7.6.15.1.4. To reduce maintenance and operating costs, the lighting system required for the facility will be designed using the minimum number of luminaires possible, providing the most suitable solution.

7.6.15.1.5. The lighting fixtures to be used along the track will be selected to withstand the harsh environmental conditions along the track (iron dust, air circulation, sunlight, etc.).

7.6.15.1.6. Tunnel lighting LED luminaires will be manufactured for tunnel lighting installations applied with busbar systems,

7.6.15.1.7. The tunnel lighting luminaire shall be resistant to shock and vibration caused by high-speed train operations, shall operate without damage under these conditions, and shall have a minimum protection rating of IP65.

7.6.15.1.8. The general characteristics and protection classes of the luminaire types to be used are shown in Table 7.10.

Table 7.10 : Luminaire characteristics and protection classes

Area	Luminaire Type	Required Minimum Luminaire IP Class
Passenger Areas		
Platform (general), Concourse (general), Escalators and stairs, Connecting passages/tunnels	LED luminaire	IP54
Platform edge (along the yellow line)	LED lighting fixture	IP54 (if full-length PSDS is present) IP65 (if no PSDS is present)
Platform exits (between the end of the passenger area and the start of the tunnel/viaduct), Stairs leading to the street	LED lighting fixture, weatherproof	IP65
General toilets	LED lighting fixture, recessed	IP42
Pedestrian areas, entrances to technical structures with ground-level access (where applicable) and emergency exit stairwells, areas in front of lifts for disabled access (ground level), external car parks, access routes/areas to station entrance structures	LED floodlight	IP66
Staff Facilities and Building Areas		
Office areas, Station control rooms, Staff rooms, OCC Control Centre	LED lighting fixture, volumetric	IP54
Changing rooms	LED lighting fixture, recessed	IP54
Staff corridors	Recessed LED lighting fixture	IP54
Technical corridors, storerooms, equipment rooms, switchboard rooms, under-platform areas, various (electrical, mechanical, etc.) shafts, lift shafts, emergency escape staircases (if any)	LED lighting fixture, waterproof	IP65
Drainage and waste water pump pits	LED lighting fixture, waterproof	IP66
Staff toilets	LED lighting fixture, recessed	IP42
Tunnels/Viaducts		
Walkways, emergency escape staircases (if any), tunnel connection (cross passage, CP) areas,	LED lighting fixture, waterproof	IP65
In switch points	LED floodlights, waterproof	IP65
Viaducts	LED floodlight, pole-mounted, weatherproof	IP66

Area	Luminaire Type	Required Minimum Luminaire IP Class
Outdoor Lighting	LED floodlight, weatherproof	IP66

7.6.15.1.9. For LED lighting fixtures to be used in passenger areas, office areas, platforms and station entrance structures, the luminous efficacy per watt shall be a minimum of 120 lumens/watt. For LED lighting fixtures to be used in other areas, the luminous efficacy per watt shall be a minimum of 100 lumens/watt.

7.6.15.1.10. The colour rendering index (CRI) of LED lighting products shall be 80% or higher.

7.6.15.1.11. The power factor of LED lighting products shall be ≥ 0.90. The economic life of all LED lighting fixtures shall be at least 50,000 hours (the period during which the luminous flux decreases by 30% compared to its level at the time of initial commissioning).

7.7. EARTHING, LIGHTNING PROTECTION, PROTECTION AGAINST OVERVOLTAGES

Earthing, lightning protection and internal and external surge protection systems shall be designed to ensure the safety of the facility, personnel and equipment.

Internal overvoltages refer to voltage surges that may occur on medium-voltage or low-voltage AC or DC system components as a result of any transient condition within operational conditions.

External overvoltages, on the other hand, are voltage surges that may occur due to external influences (atmospheric, static charge build-up, etc.).

In general, the earthing design for MV, LV and lightning protection systems shall comply with the following standards and regulations, without limitation, as well as other relevant internal and external electrical installation regulations and standards.

- Regulation on Earthing in Electrical Installations of the Ministry of Energy and Natural Resources of the Republic of Turkey
- IEEE Std. 80 Guide for Safety in Substation Grounding
- TS HD 60364-4-41/A12 Protection Against Electric Shock
- TS HD 60364-4-43/D1 Protection Against Overcurrent
- TS HD 60364-5-54 Earthing Arrangements and Protective Conductors
- DIN 18014 Basic Earthing
- TS EN 50122-1/A3 : Measures for protection against electric shock

- TSE EN 62305 Standards
- TS EN 50310/A1 Equal potential bonding and earthing in buildings with telecommunications equipment
- TS EN 50522 Earthing of power installations exceeding 1 kV

Selective, multi-stage overvoltage protection systems will be designed specifically to protect sensitive electronic equipment and other installation components. In low-voltage main and secondary distribution boards, protective measures against both external overvoltages from the mains and internal overvoltages originating from the system itself shall be taken into account in the design. To this end, protective surge arresters shall be used for sensitive electronic devices operating in the installations supplied by these distribution boards, taking into account the basic insulation levels of these installations. Where necessary, these surge arresters will be installed in main and secondary panels in a multi-stage configuration, suitable for sequential and selective operation. In the event of these protective devices operating, the residual voltages remaining on the facility will be at a level that will not cause damage to the facility or to the sensitive electronic boards and circuits operating within it.

The types and classes of surge arresters will be determined by the relevant calculations. In the selection of surge arresters, the maximum impulse withstand voltage of the insulator and the lightning impulse current will also be taken into account.

Surge arresters shall be compatible with the system's rated operating values and comply with the TS EN 61643-11/A11, TS EN 62305 and TS EN 60364-5-54 standards. Care shall be taken to ensure that the insulation levels for which the system is designed are not exceeded.

Metal-oxide surge arresters with silicone bodies shall be installed in the cable compartments of the medium-voltage main power input cells.

In electrical installations, whether in low or high-voltage systems, damage to equipment within the facility caused by overvoltages that may occur during transient conditions arising from normal or abnormal operating conditions—such as switching, disconnection or short circuits—will be prevented.

For protection against internal overvoltages, internal lightning protection units of different classes or types, as specified in the calculations, shall be used in the systems listed below.

- Main switchboards
- Sub-panels
- UPS and other critical equipment, and the panels or sockets they supply

7.7.1. Earthing

7.7.1.1. General

Earthing installations shall be designed to prevent hazardous contact and step voltages and to provide protection against atmospheric voltage discharges such as lightning and insulation faults.

Earthing conductors shall be made of flexible, stranded, electrolytic copper and shall be sized to carry the highest short-circuit currents that may be expected within the facility, without causing damage to materials and equipment, within a time sufficient for protective devices to operate.

When sizing the fixing elements used for earthing connections, the maximum fault currents shall be taken into account.

In the earthing system, all parameters for which standards and regulations specify limit values (touch voltage, etc.) shall remain within the limits permitted by these standards and regulations. To this end, all calculations required by the relevant standards, regulations and/or calculation methods shall be carried out prior to manufacture and submitted to the Authority in the form of a report.

The earthing system shall be of the TN-S type and shall be designed such that the earthing network resistance does not exceed 1 Ω.

The design of the earthing system must ensure conditions that minimise the effects of transient regimes and interaction with adjacent earth electrodes.

In the projects, the general earthing system and all its subsystems, along with their respective routes, detailed cross-sections and quantities, shall be shown.

When each element in the system is earthed, particular care must be taken to ensure that the total impedance per phase is very low.

The earthing of medium-voltage equipment (medium-voltage cables, transformers, switchgear) fitted with protective earthing will trip the system by activating the earth fault protection circuits of the relevant protective relays. Information regarding such a ground fault will also be reported to the operator via SCADA, clearly indicating the location and nature of the fault. Such a fault will be isolated within the shortest possible time, preventing damage to the facility and ensuring no harm to human life.

The shields of medium-voltage ring cables and other signal-carrying control cables will be earthed at one end only, whilst the other ends will remain open. This will prevent circulating currents from flowing.

If installed, the screens of medium-voltage cables supplied by the local electricity company will be earthed by the local electricity distribution company.

All low-voltage (signalling equipment, SCADA, communication, etc.) and high-voltage (medium-voltage switchgear, low-voltage equipment, UPS, etc.) earthing systems within the system shall be installed separately. Low-voltage earthing will be collected on low-voltage earthing bars, and high-voltage earthing will be collected on high-voltage earthing bars, and then carried to the earthing network via separate conductors.

Earthing system test pits will be provided at the street level of the railway facilities. The test pits will be provided with protection and operational earthing terminals that will be connected to the related main busbars located in the facility electrical rooms. The quantity of the test pits for a facility will be determined by the size of the facility.

A separate insulated earthing cable shall be run from the earthing bar of the LV main distribution panel to each LV sub-distribution panel.

The cross-section of the protective conductors to be used for the sub-panels shall not be smaller than the cross-section of the neutral conductor of the supply cable for the relevant panel.

Earthing cables laid for facility earthing and low-voltage systems shall be provided with yellow-green insulation.

7.7.1.2. Earthing in Underground Structures

In station, two main equipotential bars will be installed beneath the platform, one at each end. These two bars will be interconnected via an uninsulated earthing cable with a cross-section of at least 120 mm² running beneath the platform.

MV-LV equipment room (electrical equipment room) will be furnished with two equipotential busbars, which will be connected to the under platform busbars by 120 mm² earthing conductors.

In single MV-LV equipment room stations: a single earthing conductor shall be installed via the shortest route from one of the low-voltage earthing equipotential bars in the signalling room or the communications room to the low-voltage earthing equipotential bar in the earthing manhole, and connected thereto.

In all stations, earthing conductors shall be provided to connect of the main equipotential bars to earthing busbars located in the signalling and communications rooms.

An earthing conductor of suitable cross-section will be laid between the low-voltage earthing equipotential bars to be installed in the signalling room and the communications room to ensure connectivity.

In the scope of the system, a single insulated functional earthing conductor will be installed and connected between the VLD (voltage limiting device) units located in the relevant technical room on the platform level and the nearest main equipotential bar beneath the platform.

Tunnel structural earthing will be connected to the earthing busbars of the underground facilities.

The operational earthing resistance obtained by directly earthing the neutral point of the auxiliary service transformer shall remain within the limits permitted by the relevant standards/regulations. The neutral point operational earthing connections shall be provided with earthing cables of calculated cross section and connected to a separate operational earthing busbar.

Protective and operational earthing shall be connected at a single point which can be disconnected when required.

7.7.1.3. Structural Earthing of Facilities

A structural earthing system shall be implemented in all buildings and station structures along the line.

For the structural earthing, steel strips (with a cross-section of at least 30 x 3.5 mm) or round steel bars (with a diameter of at least 10 mm) shall be used in conjunction with the reinforcing steel of the building/structure, starting from the building's/structure's foundation. The steel materials (strips or round bars) shall be corrosion-resistant and hot-dip galvanised to a minimum thickness of 45 microns.

Galvanised steel strips or round bars, connected to one another to form meshes of no more than 20 x 20 metres in size, shall be attached to the reinforcing steel of all reinforced concrete surfaces surrounding the station or building structures; these structures shall be wrapped both horizontally and vertically to form a cage structure.

For the connections between the steel materials (strips or round bars) and the reinforcement, the methods specified/approved by the Authority (welding methods or special connection fittings recommended by the manufacturer in accordance with the installation instructions) shall be applied.

The main earthing system shall, under normal conditions, be incorporated into the general earthing system at station structures along the line. However, where necessary, it may be isolated from the general earthing system for the purposes of the cathodic protection system. The connection leads of the main earthing system to be installed during the construction phase at stations and other structures shall be terminated by means of removable connections to the main equipotential earthing bars under the platform and the protective earthing bar in the MV equipment room (with a connection to each bar) during the electromechanical works phase of the relevant structure.

Where interconnecting passage tunnels for an entire building and similar other structures are present, a cage structure shall be established throughout the building, and flexible connections shall be applied at structural separation points (expansion joints). The cross-sections of these flexible connections shall be selected in accordance with the relevant calculations and shall not be smaller than the cross-sections of the ends they bridge. Connection transitions shall be installed in a manner appropriate to structural requirements.

7.7.1.4. Earthing Grid

In addition to the main earthing at stations and other structures, an earthing grid shall be installed. The earthing grid shall be installed in such a way as to form a closed circuit. This closed circuit shall be divided into transverse and longitudinal loops. This looped structure shall also be connected to deep earth electrodes. The number of deep earth electrodes and grids, as well as the distances between conductors, will be determined following calculations carried out in accordance with relevant standards, regulations and calculation methods.

Cylindrical solid copper electrodes (rods) shall be used as deep earth electrodes; steel-core or copper-clad electrodes shall not be used.

Flexible, braided, electrolytically bare copper conductors will be used as the earthing grid conductors. These conductors will be connected to one another via a parallel conductor connection, and sufficient slack will be provided to accommodate underground expansion movements. The cross-sectional area of these conductors will also be determined based on calculations carried out in accordance with relevant standards and will not be less than 120 mm².

Thermal welding methods will be used to connect the components forming the earthing grid, and the necessary measures will be taken to prevent corrosion.

Sufficiently redundant branches (main earthing terminals) taken from the earthing grid will be connected to the main equipotential bars located beneath the platforms at stations, and to the main equipotential bars situated in suitable locations in other structures (with a connection to each bar), without causing damage to the insulation of the structures. During the installation of these connections, the utmost care will be taken to ensure that the insulation of the structures is not compromised; all necessary measures in this regard will be taken into account during the design phase.

For these leads as well, flexible, braided, electrolytically uninsulated copper conductors shall be used. The cross-section of the leads shall be determined as a result of calculations carried out in accordance with the relevant standards and shall not be less than 120 mm².

7.7.1.5. Earthing Connection Boxes (Manholes)

Earthing manholes shall be installed to enable the necessary measurement and inspection procedures to be carried out and to connect the earthing conductors.

In substations, the number of earthing manholes shall be at least equal to the number of MV equipment rooms in the relevant building. Depending on the condition of the buildings, the Building Inspector/Authority may make changes to the number of manholes and their locations.

For operational earthing, protective earthing and low-voltage system earthing, three corrosion-resistant equipotential bars shall be installed in each manhole, and the earthing conductors shall be connected to these bars in a removable manner.

Warning and hazard signs indicating which building the manhole belongs to shall be placed on the manhole. Durable labels indicating which system the earthing bars belong to shall also be affixed to the bars inside.

The cross-section of the earthing bars to be installed inside the manhole shall be at least equal to that of the conductor connected to them.

Measures shall be taken to protect the conductors inside the manhole against theft and similar external influences, and the covers shall be designed to be lockable.

Measures to ensure the interior of the manhole remains dry, and to prevent water accumulation and ingress, shall be taken into account in the design.

The necessary infrastructure/reservations (pipes, cable ducts, etc.) for the earthing lines to be installed between the manholes and the MV-LV equipment rooms shall be designed.

7.7.1.6. Tunnel Earthing System, Condition of Structural Reinforcement

Infrastructure will be designed to enable the measurement method described in the TS EN 50122-2 standard for testing any insulation issues between rails and earth.

A continuous structural earthing system will be installed along the line within the tunnel area and in station structures. To this end, an earthing system will be installed in the structural steelwork of stations and tunnels, connecting tunnel segments (TBM) and tunnel lining segments (NATM) along the tunnel axis to ensure electrical continuity. This continuity may be isolated via a removable connection on a regional basis to enable the measurement and testing of rail-to-ground insulation faults in a specific area at any time, or to monitor the potentials of structural reinforcement bars relative to reference electrodes.

To this end, for the tunnel structural earthing system, test/measurement and connection terminals (block-out boxes) will be installed at intervals of 200 metres along the route, unless otherwise specified by the Construction Supervisor/Authority.

Conductor continuity within the terminal boxes will be ensured via removable connections on the test/measurement and connection terminals (block-out boxes).

These connections will provide testing and measurement capabilities on the earthing system. In terms of cross-section and installation, the system will be installed in such a way as to safely carry any potential fault and error currents. Connections will be made using stainless steel connection elements.

When establishing the tunnel earthing system, the tunnel segments and linings shall be connected peripherally during the construction phase, prior to the pouring of the second-phase concrete. In this way, the segments and/or linings will be ready for connection throughout the tunnel using the terminals obtained from the connections that will remain beneath the concrete.

Metal service pipes and cable shielding within the tunnel and station structures shall be electrically isolated from the reinforcement of these structures. Furthermore, metal service pipes and cable shielding entering and exiting the system shall be isolated at the system entry points, and no permission shall be granted for the transmission of potential faults and reference potentials from the external environment or adjacent systems.

7.7.1.7. Potential Equalisation, Building Protection System

Within the operational complex, in metallic conductive structures such as cable trays, mechanical installations and their components (ventilation ducts, fire protection and firefighting system pipes, sanitary plumbing pipes, etc.), which should not be electrically active under normal conditions, a potential equalisation system shall be installed to provide protection against any contact voltages that may arise under physical environmental and operational conditions. Connections from these and similar installations shall be connected to the nearest potential equalisation system.

In cable trays, earth continuity will be ensured along the entire length of all cable routes using a 6 mm² cross-section, uninsulated braided copper potential equalisation conductor. Cable trays, steel cable ducts, metal pipes belonging to mechanical systems, and similar equipment shall not be used as circuit protective conductors. In trays running one above the other or side by side, an earth conductor shall be run only to the most heavily loaded tray; connections to the other trays shall be made via branches taken from this earth conductor at intervals of 25 metres. For trays running side by side, if the horizontal distance between trays exceeds 50 cm, separate earthing conductors shall be installed; if it is less than 50 cm, the earthing conductor shall be connected only to the most heavily loaded tray, with connections to the other trays made via branches taken from this earthing conductor at intervals of 25 metres.

One fixing clamp for the tray earthing line shall be used for each tray length. (If tray lengths are 3 metres, one clamp every 3 metres) For tray turning elements (90-degree turns, 135-degree turns, T-turn elements, etc.), one fixing clamp shall also be used for each turning element. To prevent corrosion caused by battery effects, a tin-plated washer shall be used in the fixing clamp.

7.7.1.8. Protection Systems

Where power supply sockets and electrical receivers are installed along the line in stations and tunnels, protection shall be provided in accordance with the conditions specified in TS EN 50122-1/A3, depending on whether these are located within the influence zone of the OCS circuit, capacitors and discharge units shall be installed on the protection circuit. Similarly, for switches, signals and similar devices in contact with the rails forming the return circuit and located within the influence zone of the OCS, protection shall also be provided in accordance with the conditions specified in TS EN 50122-1/A3.

7.7.1.9. Earthing System and Structural Insulation

In the design of earthing systems, the necessary measures shall be taken into account in accordance with the building's insulation properties. For surfaces of buildings in contact with the ground, particularly in insulated buildings where membranes and similar materials have been applied as part of measures against the adverse effects of water and damp, the necessary precautions and application methods to prevent damage to the insulation shall be taken into account in the design.

In the earthing system, to ensure that the system is not exposed to any earth fault voltage from outside the system and to prevent interference from surrounding structures and systems, a minimum distance of 20 metres shall be maintained from such structures. Measures shall be taken to eliminate the possibility of potential drift caused by fault currents and voltages flowing from the rail system to the external environment and vice versa.

7.7.1.10. Earthing System Design Criteria

This section sets out the requirements for the selection of protective conductors and the sizing of the earthing network. The following standards and regulations shall be taken into account when selecting protective conductors and sizing the earthing network:

- IEEE Std 80-2000 / Guide for Safety in AC Substation Grounding
- Regulations on Earthing in Electrical Installations

Design and sizing may be carried out using appropriate software, or using the methods described below.

7.7.1.10.1. Determination of Protective Conductor Cross-Section

Protective conductor cross-sections;

- Based on the phase-to-earth short-circuit current values calculated using suitable software, using the formula specified in Annex B of the Regulation on Earthing in Electrical Installations, as shown in Table 7.11,
- In accordance with Table 8 of the Regulation on Earthing in Electrical Installations, as provided in Table 7.12.

the higher cross-sectional value of the two results obtained shall be selected as the protective conductor cross-section.

Table 7.11 : Formula for Selecting the Protective Conductor Cross-Section from Annex B of the Regulation on Earthing in Electrical Installations

Formula	Formula Component	Unit	Description
$A = \frac{I}{K}\sqrt{\frac{t}{\ln\frac{\theta_f + \beta}{\theta_i + \beta}}}$	A	mm²	Cross-section
	I	A	Conductor Current
	K	A*(√t)/mm²	Material Coefficient (226 for copper)
	t	s	Fault Current Duration
	Θ_f	°C	Final Temperature
	Θ_i	°C	Initial Temperature
	ß	°C	Material Coefficient (234.5 for copper)

Table 7.12 : Regulation on Earthing in Electrical Installations, (Protective Conductor Cross-Section Depending on Main Conductor Cross-Sections)

Main Conductor Cross-Section of the Installation	Corresponding Minimum Cross-Section of the Protective Conductor
S (mm²)	S_p(mm²)
S ≤ 16	S
16 < S ≤ 35	16
S > 35	S/2

7.7.1.10.2. Sizing of the Earthing Network

In calculations relating to the sizing of the earthing network, it is essential for a realistic design that soil resistivity values are included in the calculations as accurately as possible. To this end, concrete field measurement results (soil investigation reports, etc.) should be utilised for resistivity values.

Two different methods may be used in the resistance calculation of the earthing network, as specified below:

- The 'Schwarz' method, as defined by Equation 53 of IEEE Std 80-2000
- The 'Sverak' method, as defined by Equation 52 of the IEEE Std 80-2000 standard

SVERAK METHOD

The formulas and explanations for this method are provided below at Table 7.13.

Table 7.13 : Sverak Method

Formula	Formula Component	Unit	Description
$R_0 = \rho\left(\frac{1}{L} + \frac{1}{\sqrt{20A}}\left(1 + \frac{1}{1 + h\sqrt{\frac{20}{A}}}\right)\right)$	ρ	Ω.m	Soil Resistivity
	L	m	Total Conductor Length (Including rods)
	A	m²	Area Covered by the Net
	h	m	Embedment Depth of the Mesh

SCHWARZ METHOD

The formulas and explanations for this method are provided below at Table 7.14.

Table 7.14 : Schwarz Method

Formula	Formula Component	Unit	Description
$R_1 = \frac{\rho}{\pi . L_C}\left(\ln\left(\frac{2.L_C}{a'}\right) + \frac{k_1 L_c}{\sqrt{A}} - k_2\right)$ $R_2 = \frac{\rho}{2.\pi.n_R L_R}\left(\ln\left(\frac{4.L_R}{b}\right) - 1 + \frac{2.k_1 L_R}{\sqrt{A}}\left[\sqrt{n_R} - 1\right]^2\right)$	ρ	Ω.m	Soil resistivity
	L_c	m	Total Conductor Length
	L_R	m	Length of the Earthing Rod
	h	m	Burial Depth of the Grid
	n_R	pcs	Number of Rods to be Used
	A	m²	Area Covered by the Net

Formula	Formula Component	Unit	Description
$R_m = \frac{\rho}{\pi . L_C}\left(\ln\left(\frac{2.L_C}{L_R}\right) + \frac{k_1 L_c}{\sqrt{A}} - k_2 + 1\right)$ $R_o = \left(\frac{R_1 R_2 - R_m^2}{R_1 + R_2 - 2R_m}\right)$	a'		$(2ah)^{1/2}$
	R_1	Ω	Network Conductor Resistance
	R_2	Ω	Resistance of the bars
	R_m	Ω	Mutual Resistance Between Conductors and Bars

The values of k_1 and k_2 in the above formulae are calculated using the method specified in Figure 25(a) and (b) of IEEE Std 80-2000.

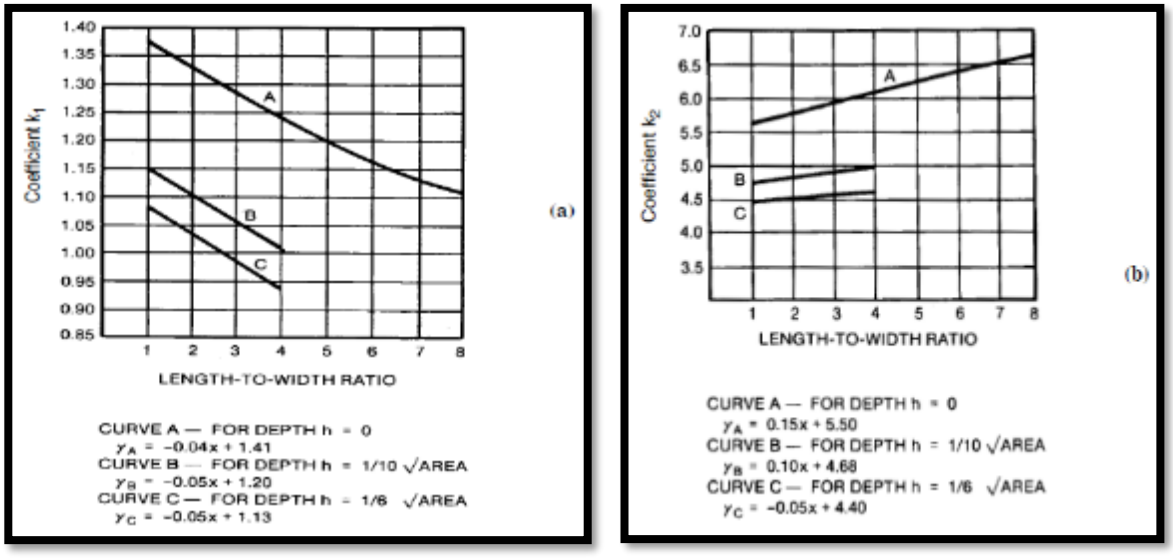


Figure 7.1 : The values of k_1 and k_2 given in Figure 25 of IEEE Std 80-2000

Table 7.15 : Calculation table for k1 and k2 values

h	k_1	k_2
0	- 0.04α+1.41	0.15α+5.50
$1/10\sqrt{A}$	-0.05α+1.20	0.10α+4.68
$1/6\sqrt{A}$	-0.05α+1.13	-0.05α−4.40

It must be verified by calculations using both the Schwarz and Sverak methods, the details of which are given above, that the earth network resistance remains below 1 Ω.

7.7.2. Lightning Protection

Lightning protection shall be designed to ensure the safety of installations and personnel in areas exposed to atmospheric effects (buildings in storage and maintenance areas, viaducts, and other above-ground structures).

A risk assessment shall be carried out in accordance with the calculation methods specified in the TSE EN 62305 standard to determine the structures on which the lightning protection system is to be installed.

Based on the results of the calculation, the minimum requirements to be met by the lightning protection system to be installed against external overvoltages shall be as follows, without limitation:

- Compliance with national and international standards (TS EN 62305 Standards, TS 13709, NFC 17-102, etc.) and applicable laws and regulations shall be ensured.
- The type of protection to be used shall not include radioactive lightning conductors and/or similar types, the use of which is wholly or partially prohibited worldwide.
- A Faraday cage or active lightning protection system shall be used.
- Where active lightning protection systems are used, systems that have undergone actual lightning testing shall be employed.
- Thermal welding or suitable connectors shall be used for all underground connections.
- The system design shall take into account the corrosion phenomenon arising from the contact of two different metals. The use of different metals shall be avoided as far as possible.
- Under the driest and most adverse weather conditions, the earth resistance shall not exceed 5 ohms.

- The entire system will be designed to operate for at least 25 years without any loss of performance.

In the design of the Faraday cage system, the following points will be taken into account;

- The following methods will be utilised in the design:
    - Rolling sphere method
    - Mesh method
    - Protection angle method
- The distances between down conductors, the maximum rolling sphere radii, mesh sizes and protection angles shall comply with TS EN 62305-3, depending on the protection classes in the lightning protection system.

Table 7.16 : Maximum rolling sphere radii, mesh sizes and protection angles according to protection classes (TS EN 62305-3)

	Protection method		
LPS Protection	**Rolling Sphere Radius**	**Mesh Sizes (m)**	**Protection Angle**
I	20	5x5	As specified in TS EN 62305-3.
II	30	10 x 10	
III	45	15 x 15	
IV	60	20 x 20	

Table 7.17 : Distance between down conductors (TS EN 62305-3)

LPS Protection	**Distance between down conductors**
I	10
II	10
III	15
IV	20

- The capture point shall be made of stainless steel or copper; its dimensions and positions shall be determined in accordance with the Rolling Sphere or Protection Angle method.

- The arrestor tip base shall be designed to keep the arrestor tip perpendicular to the ground in areas where the roof is sloped. The arrestor tip base must be designed to securely fasten both the arrestor tip and the roof conductor together. For arrestor tips longer than 3 metres, portable-base arrestor tips and special bases providing mounting strength shall be used. In lightning protection systems for flammable, combustible or explosive structures, the complete insulation of the capture rods using special insulated bases and bracket systems, taking into account the structural characteristics, must be considered in the design.
- The down conductor shall be routed to earth via the shortest possible route, and no sharp bends shall be made.
- Connection/fastening elements (clamps) shall be installed at the intervals specified in the TS EN 62305-3 standard. Down conductors shall be seamless. If splicing is necessary, thermowelding shall be the preferred method. Splicing may also be carried out using suitable mechanical fasteners.
- The manhole shall be of dimensions that allow for easy installation and shall incorporate an equipotential busbar on the inside.
- The test clamp shall be made of a material that does not corrode when in contact with the down conductors. It is preferable that the clamp allows disconnection without altering the position of the conductors running down from the roof to the earth electrode. All bolts, nuts and washers shall be made of stainless steel or copper.
- Measures will be taken to protect against step and touch voltages. Physical barriers will be installed and/or warning signs erected to minimise the risk of access to or contact with the down conductor. Furthermore, within a radius of at least 5 metres from the point where the down conductors reach ground level, a layer of insulating material such as asphalt, 5 cm thick (or a 15 cm thick layer of gravel), generally reduces the risk to an acceptable level.
- If the ground is soft, solid copper earthing electrodes with a diameter of at least 20 mm and a length of 1.5 metres shall be used. If the ground is rocky and the earthing rod cannot be driven into the ground, copper earthing plates measuring 50 x 100 cm and 2 mm thick shall be used. If there are metal structures or other earthing devices in the vicinity of a building protected by the mesh method, equipotential bonding must be carried out with these structures.

In the design of an active lightning protection system, the following points shall be taken into account:

- An Early Streamer Emission (ESE) electrostatic active lightning arrester shall be used.
- An insulating arrangement shall be provided to ensure that the active section is less affected during lightning discharge.

- The active lightning protection system head;
    - shall be a lightning arrester capable of generating a surge voltage.
    - It shall be made of a material that is resistant to chemical corrosion.
    - It shall withstand a lightning test current of 100 kA, Class H, as specified in the TS EN 62561 standard, and no visible damage shall result from the test. Photographs taken during the test and certificates obtained from the laboratory confirming the absence of damage shall be submitted by the Contractor.
    - It shall be manufactured in accordance with TS 13709/T1 and NFC 17-102 standards.
- A test laboratory report demonstrating the lightning arrester's compliance with the NFC 17-102 standard must be provided.
- The lightning arrester's protection zone shall be determined based on the minimum Δt value, not the average Δt value obtained from the tests.
- The lightning conductor shall be mounted on a pole at least 4.5 metres in height and at least 2 inches in diameter. If the lightning conductor pole is taller than 7 metres, it shall be secured with guy wires at a minimum of three points. The lightning conductor pole shall be capable of safely supporting the lightning conductor and shall be robust and durable, withstanding all weather conditions and external factors.
- The lightning conductor shall be installed at the highest possible point on the building.
- All metal fixtures within 1 metre of the down conductor (handrail bars, antenna masts, etc.) must be securely and electrically connected to the lightning protection down conductor. The connections must be made from the same material as the down conductor. However, these connections must be designed to prevent corrosion and ensure good conductivity.
- The down conductor shall be insulated with a minimum cross-section of 2x(1x50 mm²). It shall be routed to the test terminal via the shortest possible route, and no sharp bends shall be made. The conductor shall be surface-mounted in accordance with the dimensions specified in TS EN 62305. The down conductor shall be seamless. If splicing is necessary, thermowelding shall be used.
- The test terminal shall be positioned 10 cm above the protective conduit. The test terminals shall be housed within a plastic cover, made of copper or brass and specially manufactured for this purpose, and securely fastened with galvanised clamps.
- The down conductor shall be routed from the test clamp down to the point where it connects to earth using a 2x(1x50 mm²) solid copper conductor, with approximately 0.5 metres of the conductor remaining within the ground, and shall be housed within a protective conduit with a diameter of approximately 32 mm (5/4 inches) and a length of 3 metres. Equipotential bonding shall be carried out at ground level.

- The earthing electrodes shall be made of solid copper, 1.5 metres in length and 20 mm in diameter, and shall be driven into the ground to a depth of 0.50 metres below the frost line. The distance between them shall be at least twice the length of the electrode. The earth resistance shall be less than 5 ohms.
- All connection components used above or below ground shall be made of stainless steel or copper.

7.8. CORROSION CONTROL

7.8.1. General

A comprehensive corrosion prevention study for the system will be carried out; a complete system solution will be proposed, taking into account factors such as the system's route layout, topographical features and environmental conditions. Within this system solution, issues relating to construction techniques, system protection earthing and other similar systems will be collectively assessed and prepared in the form of a design report. In particular, this study will include the corrosive changes in the soil along the route, their potential effects on structures, measurements and calculations, and the identification of the associated potential corrosion risk and rate. Based on these findings, a cathodic protection system will be installed where necessary. Should such a system be required, a system capable of best addressing the corrosion rate will be installed in terms of design.

Within the scope of this system, separate test/measurement and connection terminals (block-out boxes) for earthing system will be installed along each line in the tunnels and viaduct sections.

7.8.2. Cathodic Protection

In areas at risk of corrosion due to physical environment and operational conditions, a cathodic protection system may be implemented to extend the service life of the installation, in accordance with the conditions set out under the heading "6.19.1. General".

Cathodic protection constitutes only a part of the measures to be taken against the risk of corrosion. As part of the measures to be taken against natural corrosion, an infrastructure will be established to ensure a service life of at least 100 years, such that the entire line and station structures can be incorporated into the cathodic protection system. The determination of the need for such protection and the selection of one of the numerous protection types capable of meeting this need will be based on site observations and measurements.

To this end, reinforcement continuity will be ensured along the entire length of the line, and suitable terminals will be installed between the reinforcements of different structures. These terminals will ensure reinforcement continuity at transitions between different structures and provide the means for connecting the cathode terminal to the cathodic protection system.

Accordingly, the necessary studies will be carried out to determine the type of protection, as well as the type, size and placement of the anodes required for that specific protection type.

7.8.3. Installations Entering/Exiting the System

All metallic installation components entering the railway system shall be electrically insulated at the points of entry and along their route. This ensures that no potential capable of affecting the system from the outside is introduced. Similarly, the ends of cable shields entering the system shall be left open in the panels where they enter. The points mentioned above also apply to installations exiting the system.

7.9. ENERGY QUALITY AND MANAGEMENT SYSTEM

The Energy Quality and Management System will be designed as a system that is consistent with and/or compliant with the fundamental principles of the ISO 50001 Energy Management System, adopting a holistic approach. Where necessary, integration with existing energy measurement and monitoring infrastructure operating on the lines will also be taken into account in the design.

The energy measurement and monitoring infrastructure, software and compensation system to be designed will ensure that, in addition to power factor correction, the harmonic limit values specified in the relevant legislation regarding power quality are not exceeded. If the railway line to be designed intersects with any of the existing rail system lines at a point and if energy measurement and monitoring software is already present on the existing rail system lines, there is no need to install new energy measurement and monitoring software. Integration will be provided with the energy measurement and monitoring software currently in use by the existing line(s), via the fibre infrastructure, at the point or station where the line intersects with the existing line(s).

The system will be designed with the capacity to analyse transient events and harmonics, and with sufficient communication speed for this purpose.

All power quality recorders, power analysers and other devices to be used in the system shall be compatible with the MODBUS TCP/IP protocol.

The current reactive power limit values and harmonic limit values specified in the relevant legislation shall never be exceeded. The reactive power and harmonic values measured in meters billed by the local electricity distribution company shall not only remain below the limit values but shall also be maintained at very low levels acceptable to the Authority.

With the system to be designed, in order to avoid being subject to reactive power charge billing and local electricity company penalties related to harmonics, within the framework of the relevant

current legislation, in all operating conditions of the facility—whether under overload conditions or no-load conditions corresponding to off-peak hours (taking into account the capacitive contribution of medium-voltage cables), the facility's reactive power consumption and the total harmonic distortion of current and voltage will be ensured not to exceed the permitted limits under any circumstances.

The system shall not pose any risks that could cause resonance frequencies or harmonics in any way. By its design, the system shall be one in which current and voltage are monitored in real time. Traditional electromechanical contactor-based systems shall not be used.

A selection of the standards and regulations (not limited to the following) that must be complied with regarding the Power Quality and Management System is provided below:

- Regulation on Service Quality in Electricity Distribution and Retail Supply
- Regulation on Customer Services in the Electricity Market
- Regulation on the Continuity of Supply, Commercial and Technical Quality of Electrical Energy Supplied via the Distribution System in the Electricity Market
- Electricity Projects Preparation and Electricity Installations
- Energy Efficiency Act
- TS EN 50160/A3
- TS EN 61000-4-30/A1
- TS EN 61000-4-7/A1
- TS EN 61000-4-15
- Current laws and regulations relating to energy efficiency and renewable energy

Software to be established within the Energy Quality and Management System and suitable for operation under current operating systems (including any existing software on the line to be integrated, if applicable), along with consumption values measured at the Medium Voltage level within the system (current, voltage, instantaneous active power, instantaneous reactive power, total active and reactive energy, cosφ), reactive ratios and directions (capacitive or inductive), and harmonic values will be monitored. These measurement values, taken in accordance with the relevant legislation, will be collected cumulatively on a monthly basis and, if required, for other periods, and it will be monitored that the values for the relevant period remain below the specified limit values. In the event that the target values cannot be achieved due to reasons such as equipment or system failure, or insufficient system capacity, this error and warning will be reported immediately. The software will establish a system automation for this purpose. In this way, a statistical relationship will be established between the seasonal trends in total energy consumption from various supply sources and the capacity of the existing system.

The system will be designed with the capacity to perform transient event analysis and harmonic analysis, and with sufficient communication speed for this purpose.

Details regarding the analysers, quality recorders, and other components to be installed in the system will be implemented as follows.

- Current, voltage, active power and reactive power measurements at all main energy inputs, as well as the power quality measurements specified in the TS EN 50160 standard, will be carried out using EPDK-compliant Power Quality Recorders that measure in Class A in accordance with the same standard and TS EN 61000-4-15 and TS EN 61000-4-30. The measured values will be transferred to the Energy Quality and Management System software.
- The traction power and auxiliary power measurements will be recorded separately in kWh, kVARh (inductive reactive) and kVARh (capacitive reactive) and transmitted to the Power Quality and Management System. To this end, Class B energy analysers will be installed on the medium voltage side of each traction and internal service transformer.
- Reports on the consumption (energy) data for the active power, auxiliary power and load groups of the entire system can be monitored via the Power Quality and Management System in the form of hourly, daily, monthly and annual tables showing both total and individual values; these can be exported to Excel and printed.
- Type B energy analysers shall have a sampling time of no more than 0.16 ms and shall be of the type with internal or external memory (minimum 2 MB).
- The loads in each LV main distribution board shall be grouped as shown below so that they are supplied from separate busbars, and Type B energy analysers, which measure the total energy consumed, shall be installed at the head of each busbar group.
    - ∑ Lighting-Socket/Power (optional)
    - ∑ Mechanical Loads (optional)
    - ∑ Pumps – Mechanical Loads (mandatory) – Power (mandatory)
    - ∑ Ventilation (mandatory)
    - ∑ Escalator-Lift (mandatory)
    - ∑ UPS – 110V DC Battery Charger – PSDS – EnYS (mandatory)

Current, voltage, instantaneous active power, instantaneous reactive power, total energy and cosφ data from each analyser will be transferred to the Power Quality and Management System software.

Within the scope of the system, one workstation equipped with a 23.8” or 24” screen will be installed at the OCC Control Centre. The human-machine interface on this workstation will possess the necessary software licence and features to monitor system summaries, station summaries, detailed station and system-based displays, and alarms. The graphical symbols used in these displays will be designed in accordance with the IEC 60617 (Graphical symbols for diagrams) standard. The SCADA printer at the OCC control centre may be used for Energy Quality and Management System screen captures, alarm and report outputs, and real-time colour screen capture outputs.

7.9.1. Compensation System

The automatic compensation system to be designed will ensure that the reactive power limit ratios measured at meters billed by the Local Electricity Distribution Company never exceed 70% of the current limit ratios specified in the relevant legislation. To this end, the compensation system will be designed to cover all facilities.

With the system to be designed, to avoid exposure to reactive power penalty charges by the local electricity distribution company, within the framework of the relevant current legislation, the facility’s reactive power consumption charge will be ensured not to exceed the permitted limits under all operating conditions—whether under overload conditions or during off-peak hours (taking into account the capacitive effects of medium-voltage cables and whether transformers are in or out of service), the facility’s reactive power consumption charge will be ensured not to exceed the permitted limits under any circumstances.

The system shall not pose any risks that could cause resonance frequencies or harmonics in any way. By its design, the system shall be one in which current and voltage are monitored in real time. Compensation system equipment (shunt reactors, capacitors, etc.) shall be switched on and off using thyristor modules.

In the design of the compensation system, the operating range and power characteristics of the existing emergency diesel generator sets will be taken into account; the normal operation of one system will not cause an interruption in the other. The compensation system shall be capable of engaging and performing compensation using a second set value whilst the generator is in operation. To this end, the target cosØ value can be set separately for the grid and generator modes via a relay.

The compensation system shall be remotely accessible, monitorable, programmable, and capable of automatic and manual on/off control in stages.

Compensation system equipment shall be designed to be connected to the LV main distribution board in stations/buildings where the main power supply is connected.

Compensation panels shall have a minimum IP 42 protection rating.

Where systems incorporating shunt reactors and capacitors are used, the following conditions shall apply:

- In the design of the panels, the selection of shunt reactors, capacitors and stages shall take into account ease of transport, installation and operation, maintenance and repair.
- A 4-position pole-changing switch will be used to place each panel in remote control, local control, automatic control (reactive power control relay) and off-line states. The control circuit will be designed to suit this configuration. Equipment for manual control shall be installed on the switchboard to provide a backup in the event of a fault in the reactive power control relay. For this purpose, a 0-1 position switch shall be fitted to each tap (excluding fixed taps) to enable them to be switched on and off via the switchboard.
- Each reactor and capacitor stage will be protected by an NH-fused load disconnect switch with the appropriate rated current and short-circuit breaking capacity. Each reactor will also be protected against high temperatures by a separate thermistor (PTC). Temperature warning and trip signals, as well as fuse trip information, will be transmitted to the SCADA system.
- Separate fuses will be used for the panel lighting, signal lamps, fan unit and control circuit.
- The fuses for the fan unit and control circuit within the panel, as well as the NH-fused load breakers for the reactors/capacitors, will be fitted with auxiliary contacts.
- SCADA I/O and control/terminal blocks will be designed within a separate compartment to ensure the panel can be used effectively.
- A transparent plexiglass sheet with a minimum thickness of 3 mm will be installed in front of and above the copper busbar where the power supply is connected, in a manner that does not obstruct ventilation, for safety purposes.
- Control and power cables in the panels will be of different colours; all cables will be routed through cable ducts, and cables that cannot be routed through the ducts will be placed inside spiral conduits.
- Technical drawings and operating instructions relating to the panel shall be located on the front cover of the panel.
- The panel’s internal label will include the date of manufacture, total power and other technical specifications.
- Reactors and capacitors will operate without issues at ambient temperatures between -10 °C and +55 °C.
- Each reactor and capacitor group within each panel can be remotely switched on, and their status and faults can be monitored. As specified in the SCADA I/O list, there will

be two separate 24V DC power supplies for commands received by the panel and signals sent from the panel. All data exchange with the SCADA system will be at a 24V DC voltage level.

- The panels will have hinged doors and be accessible from the rear and front. There will be filtered ventilation grilles on all four sides of the panel.
- Cable entry and exit points on the panel will be at the rear and bottom, and will be sealed to prevent dust ingress.
- The panels will be manufactured from corrosion-resistant galvanised sheet metal with a minimum thickness of 2 mm.
- In accordance with the heating calculation to be carried out taking into account environmental and site conditions, the panels shall be fitted with a sufficient number of thermostat-controlled fan units of appropriate capacity.
- The operational status of the panel and each reactor and capacitor stage will be indicated by signal lamps mounted on the panel cover. The purpose of each signal lamp will be indicated by a label on the panel. Additionally, the signal lamps will be labelled with the project code on the inside of the panel (on the panel cover).
- Labels indicating which stage each piece of equipment belongs to will be affixed to the equipment of each stage.
- For fixed-ratio transformers, an NH-fused load break switch with a power rating and breaking capacity appropriate to the transformer's design shall be used; however, thyristor modules shall not be used. Where capacitors are used, an anti-resonance harmonic filter shall be employed in conjunction with a capacitor of an appropriate p-value.

The reactive power control relay to be used in the system shall be three-phase controlled, microprocessor-based and multi-functional (control, measurement, monitoring, protection and communication).

The reactive power control relay shall be suitable for thyristor operation.

Power capacitors shall have a minimum service life of 100,000 hours, be manufactured from metallised polypropylene film, be self-healing, of the fully dry type, three-phase, and manufactured in accordance with the TS EN 60831-1/AC and TS EN 60831-2 standards.

The nominal voltage (Un) shall be at least 480V. It shall be capable of continuous operation within an ambient temperature range of -10 °C to +55 °C.

It shall have internal fuse protection against overcurrent caused by frequency deviation or resonance in all three phases.

Shunt reactors shall comply with the TS EN 60076-6 and TS EN 61558-2 standards.

The shunt reactors shall be three-phase with an operating voltage of 400V.

Reactor losses shall not exceed 4%.

The reactor panel shall include protective circuits to isolate voltage spikes occurring when the shunt reactor is switched on or off.

The shunt reactors shall be mounted on the panel base using heat-resistant, high-strength rubber mounts, and any vibrations generated by the reactors shall be dampened in such a way as not to affect the panel.

Care will be taken to minimise noise levels, and the noise level for each panel shall not exceed 65 dB.

As reactors are heat sources, they will be positioned so as not to cause thermal deformation effects on other circuit components, cables, etc. Alternatively, the coils will be positioned at the rear of the panel, whilst protection and switching elements will be brought forward using a base, with the latter at the front.

Thyristor modules shall be of a monoblock design, comprising all components (thyristors, control board, cooling unit, all internal control and connection wiring, etc.), without restricting accessibility for maintenance and repair or access to the internal components.

7.9.2. Calculation of Reactive Power to be Compensated

In accordance with the Electricity Market Customer Services Regulation; consumers with an installed capacity of 50 kVA and above are obliged to pay a reactive energy consumption charge if they consume inductive reactive energy exceeding twenty per cent of the active energy they draw, or supply capacitive reactive energy to the system exceeding fifteen per cent of the active energy.

In compensation system calculations, the reactive power generated by LV loads, transformers and MV cables in all MV operating scenarios will be calculated separately for two distinct time periods (operating hours and non-operating hours).

The parameters to be considered in inductive reactive power calculations for LV loads are provided in the table 7.18.

Table 7.18 : Parameters for LV Load Compensation Calculations

Symbol	Value	Description

cosφ1	For lighting loads: 0.95 For supply boxes: 0.9 For socket loads: 0.8 For mechanical loads: 0.85	Power factor before compensation
cosφ2	1.00	Target power factor with the compensation system
k		The coefficient used for ease of calculation

The k coefficient to be used to facilitate calculations will be obtained using the formula below:

$k = \tan\varphi 2 - \tan\varphi 1$

The required k coefficient values for raising different cosφ1 values to the cosφ2 (1.00) value are given in the Table 7.19:

Table 7.19 : k Coefficient Values

cosφ1	**cosφ2**	**k coefficient**
0.80	1.00	0.75
0.81	1.00	0.72
0.82	1.00	0.70
0.83	1.00	0.67
0.84	1.00	0.65
0.85	1.00	0.62
0.86	1.00	0.59
0.87	1.00	0.57
0.88	1.00	0.54
0.89	1.00	0.51
0.90	1.00	0.48
0.91	1.00	0.46
0.92	1.00	0.43
0.93	1.00	0.40
0.94	1.00	0.36
0.95	1.00	0.33
0.96	1.00	0.29
0.97	1.00	0.25

cosφ1	cosφ2	k coefficient
0.98	1.00	0.20
0.99	1.00	0.14
1.00	1.00	0.00

The inductive reactive power (kVAR) of the substation's low-voltage loads will be calculated separately for operating hours and non-operating hours by multiplying the demand power of these loads by the k factor.

Reactive power arising from transformers will also be calculated separately for operating hours and non-operating hours, taking into account situations where transformers are taken out of service during non-operating hours for safety and other reasons.

The MV cables to be used in the railway line's MV power distribution system generate capacitive reactive energy by their very nature. The reactive power calculation formulas for MV cables are provided below. In accordance with the formulas provided below, the capacitive reactive power values for each MV cable line will be calculated separately for each MV operating scenario, taking into account whether the cables are energised or not, depending on the cross-section and length.

$Q_c = \sqrt{3} \times U_{phase\text{-}phase} \times I_c \times L$

$I_c = (U_{phase\text{-}phase} \times 2\pi \times f \times C \times L) / \sqrt{3}$

Table 7.20 : Parameters for Capacitive Reactive Power Calculations for MV Cables

Symbol	Unit	Description
Q_c	volt-ampere reactive (VAR)	capacitive reactive power
$U_{phase\text{-}phase}$	volt (V)	phase-to-phase voltage
L	kilometre (km)	cable length
I_c	ampere (A)	capacitive current
π		pi
f	hertz (Hz)	frequency
C	microfarad per kilometre (μF/km)	electrical capacitance

Based on the details provided above, the inductive reactive power arising from LV loads and transformers and the capacitive reactive power arising from MV cables shall be calculated separately for each MV operating scenario, for both operating hours and non-operating hours, and the reactive power requiring compensation shall be calculated in accordance with the details provided in the Table 7.21. The compensation system will be sized based on the calculated maximum inductive reactive power and maximum capacitive reactive power values.

Table 7.21 : Distribution of Reactive Power Requiring Compensation

		Operating Hours				**Non-Operating Hours**			
		MV Operating Scenario-1	**MV Operating Scenario-2**	**….**	**MV Operating Scenario-n**	**MV Operating Scenario-1**	**MV Operational Scenario-2**	**….**	**MV Operation Scenario-n**
Inductive	LV loads reactive power values	…. kVAR	…. kVAR	….	…. kVAR	…. kVAR	…. kVAR	….	…. kVAR
	Reactive power values of transformers	…. kVAR	…. kVAR	….	…. kVAR	…. kVAR	…. kVAR	….	…. kVAR
Inductive Reactive Power Totals		**…. kVAR**	**…. kVAR**	**….**	**…. kVAR**	**…. kVAR**	**…. kVAR**	**….**	**…. kVAR**
Capacitive	Reactive power values of MV cables	…. kVAR	…. kVAR	….	…. kVAR	…. kVAR	…. kVAR	….	…. kVAR
Total Capacitive Reactive Power		**…. kVAR**	**…. kVAR**	**….**	**…. kVAR**	**…. kVAR**	**…. kVAR**	**….**	**…. kVAR**
Reactive Power to be Compensated		**…. kVAR Inductive Or Reactive**	**…. kVAR Inductive Or Reactive**	**….**	**…. kVAR Inductive Or Reactive**	**…. kVAR Inductive Or Reactive**	**…. kVAR Inductive Or Reactive**	**….**	**…. kVAR Inductive Or Reactive**

7.10. SOLAR ENERGY SYSTEM

7.10.1. General

The Solar Energy System (SES) will be installed on the roofs or suitable surfaces of structures to be erected as above-ground facilities along the railway line (such as viaduct-type stations, buildings in the depot and maintenance area, etc.) to convert solar energy into electricity for consumption, based on the results of feasibility and amortisation calculations/analyses.

To achieve an optimised system design, feasibility and amortisation calculations/analyses will be carried out covering installation costs, electricity bill savings, and operational and maintenance expenses over the system's expected lifespan, as well as the period required for installation costs to be offset by electricity bill savings; A comprehensive design report will be prepared using

appropriate software that takes into account the building's geographical characteristics, location, climatic conditions of the region where the building is situated, and other relevant parameters; this report will include shading analyses, analyses of system losses, the annual amount of energy to be generated, and other details.

Appropriate software that takes into account the structure's geographical characteristics, location, and other relevant parameters will be used in the system design.

All system design required for connection to existing low-voltage AC power panels will be carried out in accordance with the "Regulation on Licence-Free Electricity Generation in the Electricity Market".

The system will primarily consist of solar panels, inverters, DC cables and connectors, distribution panels, metering and protection equipment, and structural support components, and will be designed for grid connection.

The system's earthing will be integrated into the existing earthing system.

The system will comply with the design and installation standards for grid-connected solar energy systems set by the Local Electricity Distribution Company and the IEEE (Institute of Electrical and Electronics Engineers).

Low-voltage loads equivalent to the calculated average power of the area to be designed will be determined, and these loads will be supplied in parallel from both the grid and the solar power plant. Meters and energy analysers will be installed at the inputs of the panels belonging to these low-voltage loads to determine and record the energy produced by the solar power plant.

During system design, care must be taken to ensure that solar panels do not interfere with one another's operation, and that inverters with an optimal MPPT (maximum power point tracker) capacity are selected.

The shading ratio must not exceed 3%.

The total capacity of the system shall be at least 15% higher than the AC output power under standard test conditions (1,000 W/m² irradiance, 25°C module temperature and AM=1.5 spectrum conditions).

The solar panels used in the design must be of the same brand, type and model, as must the inverters.

Only panels of a single model and power rating from a single brand shall be used within a single building. Panels of different models and power ratings shall not be included in the system within a single building.

7.10.2. Solar Panels (Photovoltaic Panels)

As the lifespan of a solar energy system is determined by the lifespan of the solar panels, the design should prioritise solar panels that are as long-lasting as possible and incorporate the latest technology. The panels shall comply with the TS EN IEC 61215 Standards, TS EN IEC 61730-1/AC, TS EN IEC 61730-2/AC, TS EN 62716 (Ammonia Test), TS EN 13501-5 (Ignitability Test) and TS EN IEC 61701 (Salt Test).

The solar panels shall be positioned at an angle that maximises efficiency, taking into account the roof architecture and ensuring maximum energy production throughout the year. To minimise the cost of the panel support structure and achieve high energy efficiency, the panels will be positioned at the optimum angle determined by the calculation on the south-facing side of the roof, or along the east-west axis, provided the architectural conditions are suitable. The panel support structure will be of a quality suitable for the roof architecture. Solar panels will be considered not only as a component of the energy generation system but also as a key architectural element influencing the building's appearance and aesthetics.

All solar panels shall be of polycrystalline/monocrystalline construction; however, if, during the design phase, there are panel types that are more advantageous in terms of efficiency, construction and cost-benefit, these may be optionally proposed and used subject to the Authority's approval. In such cases, the rationale for this proposal shall be documented.

The solar panels to be used in the design must have a minimum 10-year product warranty and a 25-year performance warranty.

The efficiency of the solar panels shall be at least 15.8% under standard test conditions (1,000 W/m² irradiance, 25°C module temperature and AM=1.5 spectrum conditions) for polycrystalline/monocrystalline panels.

The positive instantaneous power output tolerance of the solar panels shall be less than 5 W. Products with negative tolerance shall not be used.

To counteract power losses caused by shading, the solar panels shall be fitted with bypass diodes. Protection shall be provided to ensure no current flows through the solar panels when energy is not being generated.

Solar panels and connection components shall be selected to withstand the maximum wind speed, wind load and snow load in the region where the facility is installed.

The solar panels shall be capable of operating at a maximum system voltage of 1000V.

7.10.3. Inverter

Inverters will be used to convert the DC energy generated by the panels into AC energy (400V, 50±4.5Hz).

The inverters shall comply with the following standards: IEC 61727, IEC 62109, IEC 62116, IEC 61000, CE, VDE 0126-1-1, VDE AR-N 4105, TS EN 50438.

The inverters shall have a pure sine wave output to handle inductive loads without causing distortion. The inverters shall be grouped according to the total power of the solar panels used. The use of high-power inverters shall be considered in the design to achieve cost and labour savings.

If more than one inverter is to be used in the system, inverters of the same model from the same manufacturer shall be used. It is not mandatory for the output powers of the inverters to be identical. All power ratings shall be determined according to the requirements and system design and shall be three-phase.

The minimum DC start-up voltage and maximum DC voltage values will be selected according to the design.

In systems containing panels at different angles, it is important for the inverters to have at least 1 (one) MPPT module to ensure efficiency. Depending on the Authority's preference, a greater number of independent MPPT modules may be required in the inverters. The total number of panels in the strings connected to the MPPT modules will be equal. The maximum input currents of the MPPT modules will be equal. MPPT circuits shall be capable of operating with both symmetrical and asymmetrical loads.

The MPPT voltage range values will be selected according to the Authority's preference.

The maximum efficiency shall be at least 98.1% or the Euro Efficiency at least 97.5%.

THD (total harmonic distortion) will be less than 3%.

Inverters shall be capable of operating without issues at ambient temperatures ranging from -20 °C to +60 °C.

7.10.4. Data Logging & Remote Monitoring

The data logging system shall be capable of continuously measuring the parameters specified below, transmitting them via remote access, and recording them. Furthermore, each inverter shall be capable of storing this data for up to 5 years using its internal memory. The data shall be stored within the inverters.

- Solar irradiation – kWh/m²
- Module temperature °C
- Ambient temperature °C
- Total power generated by the solar panels
- Total power fed into the grid

The information to be transmitted to the SCADA system for the Solar Energy System is listed below:

- Inverter DC input current, voltage and instantaneous power data,
- Inverter output current, voltage, instantaneous power and frequency data,
- Total power fed into the grid data,
- Efficiency data,
- Energy production data for the current day, the last month, the last year and since installation,
- Fault information (faults occurring on panels, inverters, etc.)

One workstation and screen will be designed for data logging and remote monitoring.

7.10.5. Cables & Connectors

DC cables to be used in the solar energy system shall be high-temperature and heat-resistant, UV-resistant, double-insulated, halogen-free, lead-free (preferably), with a nominal cable cross-section approved by TÜV, and compliant with the IEC/EN 60216-1, EN 60811-2-1, EN 60811-1-4, EN 50396, and IEC 60228 standards. DC cables used for solar panel connections shall be of the 'solar-grade' type, specifically manufactured for use in solar energy systems.

DC cables shall have a minimum cross-section of 4 mm²

The maximum voltage drop in DC cables up to the inverter input shall not exceed 1%. The cables laid between each inverter and the low-voltage AC busbar at the connection point shall be of a cross-section that allows for a maximum voltage drop of 2% at the solar energy system's maximum power.

Connectors shall be of the same brand as the selected solar panels. All connectors shall be original; no equivalent or compatible connectors shall be used.

7.10.6. Distribution/Protection Panels

DC protection panels to be used prior to the inverter inputs shall contain as many 1000V DC fuses (positive (+) and negative (-)) as there are strings. The fuse rating shall be 1.25 times the Isc value.

DC protection panels will also include 3-pole (positive (+) / negative (-) / earth) surge arresters. The number of surge arresters in the panel will be one or two, depending on the number of MPPT units in the inverter to be used.

All connections will be made to the terminals within the DC protection panel. The terminals will be labelled with appropriate labels.

Appropriate cable glands or special cable entry seals (special cable entry arrangements) will be used for all incoming and outgoing cables in the DC protection panel.

If the DC protection panels and all AC panels to be used in the system are installed in an external environment, they must have a minimum IP65 protection rating; if installed in an internal environment, they must have a minimum IP42 protection rating.

7.10.7. Earthing

All electrical and electronic devices belonging to the solar energy system to be installed, the cabinets in which they will be housed, all supporting structures to be installed, and metal components, along with all auxiliary metal mounting materials, shall be earthed. On both the DC and AC sides, these shall be connected to an equipotential busbar in accordance with standards and incorporated into the existing earthing system.

7.10.8. Support Structure

The panel support structure onto which the solar panels will be placed and secured shall be designed in accordance with the architectural and structural characteristics of the building.

In the structural/static design of the relevant building, the support structure on which the solar panels will be placed and secured will also be taken into account.

The support structure, together with the system components on it (solar panels, etc.), will be designed as a single unit in accordance with TS 498, taking into account four different regions, to meet criteria such as snow load, wind load, rain load, ice load and seismic load.

The supporting structure shall be constructed in accordance with the ‘Calculated Values of Loads to be Considered in the Sizing of Structural Elements’ in TS 498 Standard and, together with the system components (solar panels, etc.), shall be capable of withstanding the maximum wind speed in the region where the facility is installed.

The supporting structure will be designed for a 30-year service life and will be resistant to rust and corrosion. The structure will be made of stainless steel, corrosion-resistant aluminium alloy, or hot-dip galvanised material.

The structural design will take into account the day-night temperature differences in the region. The panels will not be damaged by material expansion or contraction caused by temperature variations.

The structure will be designed so that the panels do not cast shadows on one another throughout the year. Layout drawings, detailed drawings, dimensions of the structural profiles, wall thicknesses, and a 12-month shading analysis report based on the layout will be prepared.

All connections shall be watertight and impact-resistant.

The entire supporting structure shall be suitable for the installation of a lightning protection system and shall be designed accordingly.

Alternative designs may be implemented subject to the Authority's approval.

Fire and moisture insulation shall be provided at the connections between the supporting structure and the roof, as well as at the cable penetrations between roofs and the building.

7.10.9. Grid Connection

A metering system shall be installed for the three-phase, 400 V (±10%), 50 Hz low-voltage electricity generated by the solar energy system, and the necessary grid synchronisation, protection and earthing shall be provided.

Surge arresters of appropriate ratings will be installed at relevant points in the system to provide protection against overvoltages.

Protection against overloads and short circuits on both the DC and AC sides will be provided using suitable fuses. Additionally, circuit breakers/switching devices will be installed to allow the system to be manually disconnected for maintenance or other reasons.

8. CONTROL AND COMMUNICATION SYSTEMS

8.1. CONTROL AND COMMUNICATION SYSTEMS

Control and Communication Systems shall consist of the following subsystems:

- Transmission System,
- Telephone System,
- Digital Radio Communication System,
- Public Address System,
- Closed-Circuit Television System,
- Central Clock System,
- Access Control System,
- Supervisory Control and Data Acquisition System (SCADA),
- Passenger Information System,
- Fare Collection System,
- Fire Detection and Alarm System,
- Train-borne Communication Interfaces (where applicable; ETCS Level 1 onboard signalling equipment shall be treated under the signalling system scope unless explicitly specified in this specification.)

Control and Communication Systems shall be capable of meeting the communication, monitoring and control requirements of the INRAIL Line management, operations, maintenance, service units and passenger areas.

Control and Communication Systems shall be designed to operate in full technical and general design integration with existing and new line systems.

Control and Communication Systems shall interface with the ETCS Level 1 signalling system, interlocking, TCC and related non-vital communication networks as required. Vital ETCS Level 1signalling equipment, onboard ETCS equipment and safety-related signalling logic shall remain under the signalling system scope unless explicitly stated otherwise.

To ensure high availability, the design will incorporate diversity and redundancy in the hardware, equipment and subsystems performing critical functions of the systems and subsystems. The TS EN 50126 standard will apply with regard to RAMS.

Where integration with an existing line is required, designs shall be carried out taking this integration into account. All necessary hardware and software additions, modifications and

corrections to the existing control centre systems to ensure compatibility and seamless operation with all relevant systems on the existing line shall be taken into account in the design.

Each station will have a communications room. The design will ensure that the local servers and gateways for the Control and Communications Systems hardware are installed in this local communications room.

Station Control Rooms (SOR) will be designed for the Control and Communication Systems at each station, and a Depot Control Room (DOR) will be designed in the Depot Maintenance Area.

To ensure that all power supply panels and cabinets serving the Control and Communication Systems continue to operate for at least 3 hours following a power supply failure, an independent uninterruptible power supply (UPS) for these systems will be provided at each station and, where necessary, in off-site structures.

The power supply for all cabinets belonging to the Control and Communication Systems will be provided from a distribution panel located in the communications room. The power supply panel and cable installations will be shown in the relevant system designs.

Equipment and panels belonging to the control and communication systems located in different areas outside the communications room will be powered via UPS distribution panels situated closest to these areas and supplied via the communications UPS.

All monitors to be used at workstations shall be 23.8” or 24” in size.

The IP protection ratings for all equipment belonging to the control and communication systems will be determined taking environmental conditions into account.

The design of the systems will also take into account operational, maintenance and fault intervention processes. To this end, when preparing system designs, solutions will be developed to facilitate operation and maintenance and to shorten fault intervention processes.

Designs will be prepared in such a way as to allow for future system expansion.

8.1.1. Standards

All equipment of the Control and Communication Systems shall comply with international standards and recommendations, as well as equivalent local standards. Wherever possible, TSE, EN, ISO, ITU-T, ETSI, IEC and UIC recommendations and standards (or their equivalents) shall be used. All equipment and apparatus shall be designed in accordance with the manufacturers’ installation and commissioning instructions.

The standards/regulations/norms that must be complied with for each specific system are listed under the respective system headings, without being limited to these.

For ETCS Level 1 signalling interfaces and safety-related control/communication interfaces, the applicable EN 50126, EN 50128/EN 50716, EN 50129, EN 50159, EN 50121 series, EN 50122, EN 50125, ERA CCS TSI Appendix A and ERTMS/ETCS Subset specifications shall be considered as applicable. Urban railway standards, where referenced, shall be used only as complementary references for passenger stations, fire/life safety, control rooms and communication subsystems, and shall not override mainline railway, ETCS Level 1 or INRAIL Line requirements.

8.1.2. Control/Monitoring Rooms (TCC, SOR, DOR, etc.) Requirements

This section sets out the design criteria applicable to the areas where control, command and monitoring activities for the INRAIL Line are to be carried out (SOR, DOR, GİM, Traffic Control Centre (TCC)). Relevant AYGM / Administration technical specifications applicable to urban commuter / mainline railway systems shall be considered as complementary references, provided that they do not conflict with ETCS Level 1, mainline railway and INRAIL Line requirements.

The conditions specified in this section for the Traffic Control Centre (TCC) apply to the establishment of a new, independent TCC for the INRAIL Line. If the railway line to be established is an extension of an existing line and integration with an existing TCC or control centre is required, the conditions of the existing control centre shall prevail to the extent approved by the AYGM / Administration.

Table8.1 : Control/Monitoring Areas, Users and Managed/Monitored Systems

AREAS	USERS	MANAGED/MONITORED SYSTEMS
SOR	Station Manager	CCTV, Public Address, Access Control, Fire Detection and Alarm, SCADA ECS Subsystem, Passenger Information
TCC	Supervisor	Signalling, SCADA, CCTV
TCC	Communications Operator	CCTV, Public Address, Access Control, Passenger Information, Radio, Transmission System
TCC	Traffic Operator	Signalling, Radio, CCTV
TCC	Depot and Maintenance Area Operator	Depot and Maintenance Area Signalling, CCTV, SCADA, Radio
TCC	SCADA Operator	SCADA (PCS & ECS), Radio

AREAS	USERS	MANAGED/MONITORED SYSTEMS
TCC	Train Communication Interface Operator	Train-borne Communication Interfaces (where applicable)
DOR	Depot Control Room Operator	CCTV, Public Address, Access Control, Fire Detection and Alarm, SCADA ECS Subsystem
GİM	Security Monitoring Centre Officer	CCTV
Security Structures (Guardhouses, etc.)	Security Officer	CCTV, Access Control*

*If the relevant security structure (guardhouse, etc.) is a building containing a large number of controlled doors, such as an administrative building located on the main route, the Access Control System will be monitored and managed. If the security structure (guardhouse, etc.) belongs to the Depot and Maintenance Area, monitoring and management of the Access Control System will be carried out via DOR; therefore, monitoring and management of the Access Control System will not be carried out from here.

The design criteria for the Traffic Control Centre (TCC) are set out below, though this list is not exhaustive:

- It shall be designed in accordance with the TS EN ISO 11064 (1-2-3-4-5-6-7) standards.
- A controller workstation, complete with software, shall also be designed to enable operators to switch between video wall displays.
- The TCC shall be designed to provide OCC operators with the necessary displays and functionality. In this regard, particular attention shall be paid to aesthetics and architectural compatibility in matters such as equipment layout and arrangements, and accepted ergonomic principles shall be applied. All designs shall be as comfortable and user-friendly as possible for the operators.
- The general layout of the TCC, including the arrangement of desks and equipment, will be designed in a U-shape and in accordance with ergonomic principles.
- To enable TCC personnel to monitor the systems from their workstations, taking into account system operational functions, human ergonomics and standard practices, the colours of all visual elements—including characters, cursors, symbols, images, shapes, etc.—to be displayed on the screens shall be selected for ease of viewing, and the text shall be of a size that ensures readability. The number of 70” Video Walls shall be designed.

- Station CCTV system
- Vehicle CCTV system
- Signalling system
- SCADA system

- At the TCC, the video walls shall be positioned in front of the workstation belonging to the same system operator.
- TCC sessions shall be designed as follows:
  - Traffic Session
  - Depot Session
  - Train / Rolling Stock Communication Interface Session (where required for driver-operated ETCS Level-1 operation)
  - Communication Session
  - SCADA Session
  - Supervisor Session

Table 8.2 : Minimum Requirements for Video Walls, Workstations and Monitors in Control/Monitoring Rooms

System / Subsystem Name	Control / Monitoring Room Name	Session Name	70" Video Wall Minimum Quantity (units)	Workstation Minimum Quantity (units)	23.8" or 24" Monitor Minimum Quantity (units)
CCTV	TCC	Communication	1 + per 4 stations 1 unit	1	3 (2 for live, 1 for recorded footage)
		Storage	1	1	1
		Traffic	1	0	0
		Supervisor	0	1	1
	QUESTION		0	1	2
	DOR		0	1	2
	GİM (Security Monitoring Centre)		10 (4 CCTV units + 6 for the GIM map)	4 (2 CCTV units + 2 for GIM)	8 (4 CCTV units + 4 for GIM)

System / Subsystem Name	Control / Monitoring Room Name	Session Name	70” Video Wall Minimum Quantity (units)	Workstation Minimum Quantity (units)	23.8” or 24” Monitor Minimum Quantity (units)
	Security Structures (Nizamiye, etc.)		0	1	2
SCADA	TCC	SCADA	For every 9 stations 1 unit	3 (1 of which is PCS, 1 ECS, 1 for a single-line diagram)	6 (2 for PCS, 2 for ECS, 2 for single-line diagram)
		Depot	2	0	0
		Supervisor	0	1	2 (1 unit for PCS, 1 for ECS)
	SOR		0	1 (for ECS)	2
	DOR		0	1 (for ECS)	2
ANNOUNCEMENT	TCC	Contact	0	1	1
	SOR		0	1 (Fire Detection and Alarm System will be used in conjunction with)	1 (Fire Detection and Alarm System will be used in conjunction with)
	DOR		0	Fire Detection and Alarm System workstation will be used	Fire Detection and Alarm System The monitor will be used
PASSENGER INFORMATION	OTCC	Communication	0	1	1
	SOR	SOR	0	1 (Access Control System will be used in conjunction with)	1 (Access Control System will be used in conjunction with)
ACCESS CONTROL SYSTEM	TCC	Contact	0	1	1
	SOR		0	The Passenger Information System workstation will be used.	The Passenger Information System monitor will be used.
	DOR		0	1	1

System / Subsystem Name	Control / Monitoring Room Name	Session Name	70” Video Wall Minimum Quantity (units)	Workstation Minimum Quantity (units)	23.8” or 24” Monitor Minimum Quantity (units)
	Security Structures (Nizamiye, etc.)*		0	1*	1*
RADIO	TCC	Communication	0	1	1
		Depot	0	1	1
		Traffic	0	1	1
		SCADA	0	1	1
ENERGY QUALITY AND MANAGEMENT	TCC	Maintenance and Monitoring Desk	0	1	1
FEE TOTAL	TCC	Maintenance and Monitoring Desk	0	1	1
FIRE DETECTION AND ALARM SYSTEM	SOR		0	The Announcement System workstation will be used.	The Public Address System monitor will be used.
	DOR		0	1 (The Public Address System will be used in conjunction with)	1 (Public Address System will be used in conjunction with)
VIDEO WALL SYSTEM	TCC		0	1 (controller workstation)	0
SIGNALLING (ETCS L1/TCC)	TCC	Traffic	1 unit per 3 stations	2	1 unit per 4 stations
		Depot	2	1	2
		Supervisor	0	1	2
	SOR		0	1	2 (view only)

System / Subsystem Name	Control / Monitoring Room Name	Session Name	70” Video Wall Minimum Quantity (units)	Workstation Minimum Quantity (units)	23.8” or 24” Monitor Minimum Quantity (units)
MAINTENANCE AND REPLAY PLAY	TCC	Maintenance and Monitoring Desk	0	1	1
TARIFF MANAGEMENT	TCC	Maintenance and Monitoring Desk	0	1	1
SIMULATOR	TCC	Traffic	0	1	2
VEHICLE ON-BOARD ANNOUNCEMENT (TRAIN PA IF APPLICABLE	TCC	Vehicle	0	1 (To be used in conjunction with the On-Board Intercom System)	1 (To be used in conjunction with the On-Board Intercom System)
VEHICLE TOP PASSENGER INFORMATION (OCCS_PIS)	TCC	Vehicle	0	1	1
VEHICLE ON-BOARD SCADA (OCCS_SCADA)	TCC	Vehicle	0	1	2
VEHICLE ROOF INTERCOM (TRAIN PIS IF APPLICABLE)	TCC	Vehicle	0	The Vehicle-Mounted Public Address System workstation will be used	The Vehicle-Mounted Public Address System monitor will be used
VEHICLE TOP CCTV (OCCS_CCTV)	TCC	Vehicle	2	1	3 (2 live, 1 for recorded footage)

System / Subsystem Name	Control / Monitoring Room Name	Session Name	70” Video Wall Minimum Quantity (units)	Workstation Minimum Quantity (units)	23.8” or 24” Monitor Minimum Quantity (units)
VEHICLE ON-BOARD RADIO (OCCS_ RADIO)	TCC	Vehicle	0	1	1
SOLAR ENERGY (SES) (if applicable)	SOR		0	1	1
	DOR		0	1	1

*If the relevant security structure (guardhouse, etc.) is a building containing a large number of controlled access points, such as an administrative building situated along the main route, a workstation and monitor will be installed for the Access Control System. If the Security Structure (Guardhouse, etc.) belongs to the Depot and Maintenance Area, a workstation and monitor for the Access Control System will not be installed here, as the monitoring and management of the Access Control System will be carried out from the DOR.

Table 8.3 : Other Hardware Requirements for Control/Monitoring Areas

Control / Monitoring Zone and Session Name	Direct-Line Telephone	Digital Telephone		Vehicle Radio	Radio Console	Operator For PC and Screen Set	Train Emergency Stop Button	Digital Clock	Public Address Console	Intercom Console	Camera Control Console	Printer*
		Standard	Emergency									
TCC Communication Session	1	1	1	1	1	1		1	1		1	2
TCC Train Communication Interface Session		1	1	1	1	1			1	1		
TCC Traffic Session	1 (mobile)	1	1	1	1	1	1					
TCC Depot Session		1	1	1	1	1					1	
TCC SCADA Session	1	1	1	1	1	1						

TCC Supervisor Session	1	1	1	1		1			1	1		
SOR	1	1	1		1			1	1	1	1	1
DOR	1	1	1		1			1	1		1	1
Security Structures (Nizamiye, etc.)		1			1						1	

*Printers: These shall be professional laser printer models capable of producing colour and black-and-white prints up to A3 paper size, capable of functioning as scanners, and equipped with sufficient memory to queue jobs and retain transaction history.

All workstations and their associated monitors to be used by operators in the Station Control Room, Traffic Control Centre (TCC) and other specified areas shall be of the same make and model. Monitors for the workstations shall be 23.8" or 24" LED monitors with a minimum resolution of 1920x1080.

The types and minimum technical specifications of the workstations, depending on the system in which they will be used, shall be determined according to applicable AYGM / Administration requirements for the INRAIL Line and the most demanding software resource requirements of the relevant systems.

The design will take into account that the PC and monitor sets to be used by operators will be supplied by the Operating Organisation, whilst the Construction Contractor will prepare the necessary infrastructure, installations and spaces for these. This will also be taken into account when designing the desks. Announcement consoles will be designed to include a microphone and headphones. If video wall screens are arranged in two rows, there will be an equal number of screens in each row to ensure screen integrity. Should additional screens be added, these will be configured as CCTV screens. The specifications of the workstation hardware shall not fall below the recommended specifications of the system requiring the highest resources among the software to be used by the operators. In particular, the hardware for systems with high resource requirements, such as CCTV, will be upgraded to the extent necessary to ensure the system operates smoothly.

User monitors shall be at least 23.8” or 24” in size, with a 16:9 aspect ratio, Full HD resolution, a wide colour gamut and wide viewing angle, anti-glare, height-adjustable and aesthetically pleasing.

Desk and chair sets suitable for the requirements will also be designed for all necessary areas, such as SOR, DOR, OCC and Security Structures (Nizamiye, etc.), for the placement of workstations and monitors.

8.1.2.1. Traffic Control Centre (TCC) Video Wall System

Controls for the workstations in the TCC shall be transmitted to the operator desks via an IPKVM (IP Keyboard-Video-Mouse) system.

Video wall control units and workstations will be located in the central communications room adjacent to the TCC (or, if there is a separate storage communications room in the depot, in the TCC main equipment room). The equipment to be placed in the central communications room (or, if there is a separate storage communications room in the depot, in the TCC main equipment room) shall be designed to be suitable for rack cabinet mounting.

The control units and IPKVM equipment to be located in the central communications room (or, if there is a separate depot communications room in the warehouse, in the TCC main equipment room) shall be equipped with redundant power supplies.

Images from the workstations shall be transmitted to the video wall screens via an IP signal.

A network switch with the necessary number of ports required for the management of the IPKVM and video wall system shall be designed.

For the video wall system on teh INRAIL Line, one of the two design types (Type-1 and Type-2), the components of which are summarised below, shall be implemented. Detailed specifications for the video wall system shall be based on the applicable AYGM / Administration requirements for urban commuter / mainline railway control centres, and shall be coordinated with the TCC architecture.

Type-1 Video Wall system components:

- Screens (LED screen or Laser-illuminated DLP Cube Screen)
- Video Wall Control Unit
- IPKVM Transmitter Unit
- IPKVM Receiver Unit

Type-2 Video Wall system components:

- Screens (LED-backlit DLP Cube Screen or -laser-backlit DLP Cube Screen)
- Control System Management Server
- Control System Decoder
- Video Streaming Hardware (Encoder-IPKVM)
- Control System Management Software

8.1.3. Transmission System

The Transmission System shall be designed as the backbone of the Control and Communication Systems. The systems to be installed within the Railway shall be connected via a fibre-optic cable infrastructure through the Transmission System to all stations, the depot and maintenance area and all associated facilities, as well as the SOR, DOR, TCC and Central Communications Room (or, if there is a separate depot communications room in the depot, the TCC Main Equipment Room and Depot Communications Room).

In the design of the transmission system, the system solution shall be selected to meet the requirements of an ETCS Level 1 urban commuter / mainline railway. The following solutions may be implemented, subject to Administration approval and compatibility with the TCC, signalling and communication architecture:

- Network Communication System (IP/MPLS)
- Industrial Network System
- Ethernet System

All necessary fibre optic and copper cable infrastructure, hardware and software, as well as the communication requirements of all systems, shall be provided within the scope of the transmission system.

As real-time audio, video, fault and other information—such as SCADA, public address and CCTV systems—shall also be transmitted via the system, particular attention shall be paid to ensuring the transmission system is designed to transmit data without corruption, freezing or loss.

The design of the transmission system, equipment selection and projects shall be carried out by selecting the most suitable topology (ring+star or star) and protocol to provide hot redundancy. The fibre infrastructure will allow for the implementation of different system topologies.

The bandwidth between the stations and the centre shall be determined in accordance with current technology. Bandwidth calculations shall be made taking into account the system’s future expansion. In all cases, the data transmission speed between the stations and the centre shall be a minimum of 10 Gbit/s.

Devices at the central site shall be Layer 3 (backbone) devices, whilst those at the stations shall be Layer 2 or Layer 3 devices. Each system shall be configured with a separate VLAN.

All switches and modules (backbone and edge) shall be of the same brand from the same manufacturer. All switches and modules to be used shall be enterprise-class models.

The transmission system’s capacity shall be sufficient to carry all voice, video, data and Local Area Network (LAN) communications for the following systems:

- Telephone System,
- Digital Radio Communication System,
- Public Address System,
- Closed-Circuit Television (CCTV) System,
- Central Clock System,
- Access Control System,
- Supervisory Control and Data Acquisition System (SCADA),
- Passenger Information System,
- Toll Collection System
- Train-borne Communication Interfaces related to the ETCS Level 1 signalling system,
- Fire Detection and Alarm System,
- Platform Screen Door System (PSDS),
- Non-vital data transmission and interfaces related to the ETCS Level 1 signalling,
- Power Quality and Management System,
- LAN communication infrastructure for operations and maintenance staff

To ensure redundancy of the transmission system, single-mode fibre optic cable lines with sufficient capacity and an adequate number of cores shall be designed for each of the two tunnels, running separately along the route and identical to one another. Each line shall be capable of operating independently. The design of the system's other equipment (such as patch panels) will also incorporate these fibre cores.

All cables to be used shall be run in one continuous length from one point to another without any splices. However, should the length of a specific cable run exceed the maximum length for which the cable can be manufactured, a splice may be made subject to the Authority's approval.

Fibre optic cabling and terminations shall comply with the IEC 61754 and ANSI/TIA/EIA-568-C.3 standards.

The switching, routing and termination equipment of the transmission system shall be designed for electronic equipment rooms (communications room, etc.) and installed in cabinets compliant with the IEC 60297-3 standard.

The fibre optic cables required for inter-base station management communication within the Digital Radio Communication System, Signalling System communication, Local Area Network (LAN) communication within the Information Processing System, and communication between OG relays shall be included in the capacity calculation. The network topologies of these systems shall be assessed within their own scopes, and it shall be noted that they may differ from the

Transmission System's network topology. The final decision will be determined during the design phase and submitted to the Authority for approval.

A sufficient number of spare fibres shall be left in the fibre optic cable. Once the required number of fibre optic fibres has been determined, a 20% excess spare fibre capacity shall be provided in the fibre optic cable in each tunnel.

Station/building internal fibre optic cables shall be designed such that each cabling runs from the panels/cabinets on all floors to the communications room within the station/building, with 12 single-mode fibres per cable.

Separate fibre optic cables, independent of the transmission system, shall be laid for the signalling system.

The system configuration shall be such that communication continues without interruption even in the event of a fault or break in the cable or circuits, or if two consecutive cables are severed. Furthermore, this configuration shall allow all stations, except the one where the fault occurs, to continue communicating even if the cabinet at a station is completely out of service. The system shall continuously self-test, and in the event of a fault, the circuit and data flow shall be automatically reconfigured.

The system's transmission medium will consist of high-quality, single-mode fibre-optic cables. The cables will be laid in each tunnel as physically separated cables, at different elevation levels on opposite sides of the track, into cable trays located beneath the walkway with tunnels and covered sections.

All active and passive components of the transmission system shall include a 20% reserve capacity. This shall allow for a 20% increase in data traffic without the need for additional equipment. Switching devices in the cabinets and panels located in the communications room and other areas shall have a 20% reserve of ports. This redundancy wshallill be calculated separately for each cabinet. No device shall be utilised at full capacity. The switching device in the communications room shall also provide a 20% reserve of fibre optic ports.

In all stations, the communication rooms to be installed in the station buildings shall contain cabinets belonging to the Transmission System. In accordance with the requirements of the railway line, data shall be collected from the subsystems in the relevant area via the switching (switch) devices located within these cabinets and transmitted to the Station Control Rooms (SOR) and the TCC.

Where distances between the equipment of the subsystems on-site and the communications room exceed the standard Ethernet cable length, edge/aggregator switching devices shall be installed at various points within the stations and complexes. The connection between the equipment of the subsystems in these areas and the edge switching device shall be provided via

an Ethernet cable. Communication between the edge switching devices and the main switching device in the communications room shall be provided via fibre-optic cable.

In the TCC, a centralised network management software must enable the configuration, management, fault logs, performance data and user activities of all transmission system equipment to be controlled and monitored.

Fibre optic cables shall comply with relevant standards and be fire-resistant (FE180 PH120), flame-retardant, low-smoke-emitting, halogen-free and rodent-resistant. In addition to these features, corrugated steel-armoured or similar armoured-type cables shall preferably be used in tunnels.

PoE switches shall be designed in a distributed configuration within stations for devices such as CCTV cameras and passenger information screens, which are located in a dispersed manner and capable of communicating via the Ethernet protocol. These switches shall also be connected to the Ethernet switches located in the transmission system cabinet. The station-internal transmission system network topology shall be a redundant star topology. Each PoE switch at the station shall be connected separately to the redundant station switches belonging to the transmission system.

CAT cabling shall be used to connect the communication room network nodes to the field equipment. The field equipment shall be connected to the network nodes via data sockets. The fixed connection distance between the network nodes and the field equipment outlets via connection panels shall not exceed 90 metres. Where the distance exceeds 90 metres, fibre-optic cables shall be used instead of CAT cables.

For operational requirements, a network system (data communication infrastructure) shall be designed for use by operational staff at stations, in offices belonging to management and maintenance units, in material stores, and in the depot andmaintenance area (maintenance workshops, etc.). This system shall be physically separate from the transmission system.

Furthermore, during the design phase, coordination shall be maintained with the Operating Organisation regarding the infrastructure for wired and wireless internet communication, the staff attendance control system, and station information boards at stations and sites; the necessary cable infrastructure shall be designed at designated points.

At least the specified number of data sockets shall be designed in the locations listed in the Table at 8.4.

Table 8.4 : Data Socket Layout Table.

Room Name	Minimum Number of Data
SOR Room*	2 units
DOR Room*	2 units
Manager Rooms	2 units
Offices for Department Heads	To be determined based on the number of desks.
Workshops (Vehicles, Fixed Installations, etc.)	2 units
Materials Store	2 units
Meeting Room	6 units
Training Room	2 units
Station Staff Break Room	2
Medical Room	1
Driver's Room (for driver-operated railway lines)	2
Office	To be determined based on the number of desks.

* Additionally, one data socket shall be installed for each workstation.

Data sockets shall be terminated in the communications room.

In the event that the transmission system shall be connected to the outside within a mandatory limited timeframe, redundant firewall devices shall be installed in the central communications cabinet to ensure protection against unauthorised access and viruses. Networks that need to communicate with each other shall be terminated on the firewall, and the necessary restricted rules for communication shall be defined.

Care shall be taken to ensure maximum protection against external physical interference with cable installations in public areas. There shall be no visible ports at accessible points.

All cabling, from distribution panels to end-user equipment, shall be routed via cable trays and conduits.

IP and VLAN planning shall be carried out during the design phase by researching the structures of existing lines within the organisation, in accordance with the specifications set by the relevant authorised/responsible bodies.

8.1.3.1. Standards

TS EN ISO/IEC 27001 Information Technology – Security techniques – Information security management systems – Requirements

TS EN ISO/IEC 27002 Information technology – Security techniques – Guidelines for the implementation of information security controls

TS EN ISO/IEC 27003 Information technology – Security techniques – Guidance on the implementation of an information security management system

TS EN ISO/IEC 27005 Information Technology – Security techniques – Risk management standard for information security management systems

TS EN ISO/IEC 27019 Information technology – Security techniques – Information security measures for the energy services industry

TS EN IEC 62368-1 Audio/video, information and communication technology equipment – Part 1: Safety requirements

TS EN 50561-1 Power line communication devices used in low-voltage installations – Radio disturbance characteristics – Limits and measurement methods – Part 1: Devices for domestic use

TS EN 55024/A1 Information technology equipment – Immunity characteristics – Measurement methods and limits

TS ISO/IEC 11801-1 Information technology – General cabling for customer premises – Part 1: General requirements

TS EN 50173-1 Information technology – Generic cabling systems – Part 1: General rules

TS EN 60695-11-20 Fire hazard test – Part 11-20: Test flames – 500 W flame test methods

TS EN 61587-1 Mechanical structures for electronic equipment – Tests for the IEC 60917 and IEC 60297 series – Part 1: Rules regarding environmental conditions, test set-up and safety aspects for cabinets, racks, sub-racks and chassis used and transported in building environments

TS EN 60529 Degrees of protection provided by enclosures (IP code) (in electrical equipment)

TS EN IEC 60297-3-110 Mechanical structures for electrical and electronic equipment – Dimensions of mechanical structures relating to the 482.6 mm (19 inch) series – Part 3-110: Residential racks and cabinets for smart homes

TS EN IEC 60917-1 Modular systems for the development of mechanical structures for electrical and electronic equipment applications – Part 1: General standard

ANSI/TIA/EIA-568-B RJ45 Termination Standard for UTP Cables

TS EN IEC 62439-3 Industrial Communication Networks – A protocol contained in the High Availability Automation Networks standard will be used.

Devices shall comply with the “TS EN 50121-4 Railway Applications – Electromagnetic Compatibility – Part 4: Emission and Immunity of Signalling and Telecommunication Equipment”.

8.1.4. Telephone System

The telephone system is a digital communication system to be established to facilitate inter-structure communication along the line. For the telephone system, an infrastructure design shall be developed that meets the requirements of the structures connected to the system along the line, as well as accommodating potential future expansions.

The Telephone System shall consist of a satellite exchange (EPABX) at the TCC and satellite exchanges (EPABX) at the stations and the Depot and Maintenance Area (remote), and shall have the capability to route both voice and data. Telephone distribution boxes shall be allocated to suitable locations on the floors of the stations and the Depot and Maintenance Area, with distribution to the end-point sockets. The telephone system to be installed shall have the capacity to meet all the telephone requirements of the railway line.

Communication between the satellite exchanges to be installed at the stations and the Depot and Maintenance Area and the main exchange at the centre shall be provided via the transmission system. Should the connection between the satellite EPABX(es) at the stations and the central EPABX be lost, the satellite EPABX(es) shall continue to operate independently. The EPABXs shall be equipped with features appropriate to the requirements (call hold, call waiting, conference calls, etc.), and the design must take into account the provision of the necessary hardware and a sufficient number of licences for these features.

The exchanges shall be designed to accommodate the railway line's internal, external and an additional 20% of telephone traffic. Consequently, the exchanges and telephone system hardware shall be designed so as not to require additional cards, racks, licences or power for the spare (unused) 20% capacity. This redundancy shall be calculated separately for analogue and digital lines. (For example, for a telephone system with 80 analogue and 20 digital subscribers, the exchanges shall be designed to accommodate 96 analogue and 24 digital subscriptions, taking into account requirements such as cards, racks, licences and power.)

The satellite EPABX switchboard shall contain analogue and digital cards, to which telephones shall be connected depending on their type. Telephone cables coming from the site shall be terminated in a distribution box (patch panels) before being connected to the switchboard's cards. Intermediate distribution boxes shall be used to minimise cable lengths. All intermediate distribution boxes shall be selected in an appropriate size, taking spares into account. However, in all cases, intermediate distribution boxes shall not be used for Emergency Telephones; these cables shall be designed to be connected directly to the patch panel in the communications room without any intermediate connections.

All cables to be used in the telephone system shall be selected in the appropriate cross-section and type according to their location (station, tunnel, etc.); the conductor diameter of all telephone cables shall not be less than 0.6 mm, and in tunnels, it will be a minimum of 0.9 mm.

All telephones to be used in the system shall be of a type that does not require power (excluding rotary-dial telephones and IP telephones unless they are PoE-enabled). The cables of the telephones shall terminate at a socket first; the cable between the socket and the telephone shall be separate.

All telephone cables shall be HFFR (halogen-free, flame-retardant), rodent-resistant and low-smoke. All emergency telephone cables shall be fire-resistant (FE180 PH120); furthermore, the cables for emergency telephones in tunnels / covered sections shall be armoured.

A telephone line shall be connected to the lift control panel for each lift car, and a separate number shall be allocated.

The status/fault records and logs of all telephones in stations and tunnels shall be monitorable from the TCC, and self-tests shall be performed outside operating hours via the same software.

The design shall incorporate a voice recording system to record telephone calls in the TCC and SOR rooms. The voice recording system shall have the capacity to store telephone calls for a period of 30 days.

The telephone and its housing shall form a single integrated product. Telephones housed in separate boxes to meet the required IP ratings shall not be accepted. This condition applies to all telephones.

8.1.4.1. General Telephones

One analogue telephone shall be specified for each technical room. All analogue telephones shall be wall-mounted and installed on the wall of the room in which they are located. In standby rooms, only telephone sockets and lines shall be specified; no telephone equipment shall be installed in these areas. However, the telephone sockets to be installed in these standby rooms shall be taken into account in the capacity calculations for the exchanges.

At platform end access points track sections and, where applicable, tunnel portals in both directions, maintenance telephones with a handset and keypad—rated to protection class IP54 if a full-height Platform Screen Door System (PSDS), if applicable is present, or IP66 if not—shall be designed for installation on the platform side, adjacent to the platform end access point or trackside access gate.

For switch areas as well (one unit at each end of cross-over areas, and one unit each switch motor area, as required for maintenance access), IP66-rated hands-free and push-button maintenance telephones shall be designed.

Four pairs of cables (two active pairs and two inactive spare pairs) shall be provided for all maintenance telephones.

Maintenance telephones shall be illuminated by a blue light (blue light station) powered continuously via the emergency lighting circuits.

One digital telephone shall be designed for each station and depot and maintenance area control room (SOR and DOR). In the TCC, a number of digital telephones equal to the number of workstations shall be installed.

A wall-mounted, enclosed service telephone shall be installed for each turnstile area.

Telephones installed in areas such as fire, drainage and sewage pump rooms shall have an IP54 protection rating. The telephone and enclosure shall form a single integrated product. Telephones housed in separate boxes shall not be accepted.

IP telephones may be used in remote areas for stations and sites of a scale that does not require a telephone exchange.

8.1.4.2. Track-Side and Station Emergency Telephones

Emergency telephones in tunnels, covered sections, stations, line-side evacuation routes and emergency access/egress structures shall be impact-resistant to at least IK10 level.

Emergency telephones in tunnels, covered sections and emergency access/egress structures shall be handset-operated and keyless. Station emergency telephones shall be single-button push-to-talk intercom type, programmable, equipped with a noise-cancelling microphone, and capable of adjusting the volume level according to ambient noise.

Four pairs of cables (two active pairs and two inactive spare pairs) shall be used for all emergency telephones.

Emergency telephones to be used in passenger areas of the station shall be of the intercom type, allowing two users to speak to each other simultaneously (full duplex). Emergency telephones shall be positioned so that they can be reached from any point in the passenger area within a maximum distance of 100 metres. At least 2 emergency telephones shall be installed on the ticket hall level, at least 1 on the mezzanine level, and 2 per platform on platforms designed for 8-car train operations; on platforms designed for 6-car and 4-car train operations, 1 emergency telephone shall be installed per platform.

The layout of station emergency telephones shall be designed to meet the requirements of NFPA 130 Standard regarding fire emergency communications.

Along the INRAIL Line, emergency telephones located in the tunnels, covered sections, bridges, viaducts, open-line sections, emergency acess/egress points and other line-side evacuation routes shall be connected to the nearest appropriate communication node, station communication room, technical building or line-side communication cabinet in accordance with the approved emergency evacuation concept and communication system architecture. The cabling and transmission architecture shall be designed with sufficient redundancy so that a single cable failure, local equipment failure or loss of one communication node shall not result in the loss of emergency telephone service over the relevant tunnel, coverede section or evacuation area.

Emergency telephones and, where required, maintenance telephones in tunnels, covered sections, bridges, viaducts, open-line sections, switch areas and technical areas shall be connected through appropriately sized and protected cables, junction boxes and communication cabinets. All outdoor, tunnel, covered section and harsh environment equipment, junction boxes and termination panels shall have at least IP66 protection class, suitable mechanical protection, clear labelling and environmental durability appropriate for the INRAIL Line.

Emergency telephones shall be illuminated by a blue light (blue light station) supplied continuously via the emergency lighting circuits.

Emergency telephones locations in tunnels, covered sections, bridges, viaducts and emergency access/egress structures shall be determined according to the approved emergency evacuation concept, tunnel safety design, applicable fire/life-safety standards and Administration requirements. Cross-passages and emergency shafts shall be equipped with emergency telephones where applicable. Fixed spacing values shall not be applied automatically unless specified by the approved safety concept; the Contractor shall submit the proposed locations, maximum spacing, redundancy concept and failure-mode analysis for approval.

When the handset of any emergency telephone along the line is lifted or its button is pressed, it shall connect directly to the Communications Operator at the TCC.

8.1.4.3. External Telephones

For payphones, direct external lines, bank ATMs and similar devices, a telephone cable or fibre-optic cable with a capacity of 30 pairs shall be run from the manhole/box belonging to the Telecommunications Service Provider (TSS) at each station to a suitable technical area within the station, and terminated in a suitable box in a designated technical room. Distribution to areas within the station shall be carried out from this box.

Telephones connected via an external telecommunications service provider shall be installed in the station and depot control rooms (SOR and DOR) and the Traffic Control Centre (TCC). The number of these telephones is specified in Table 8.3.

Two public payphones (one of which must be accessible for disabled use) shall be installed at each station concourse. To this end, cabling shall be laid from the telephone junction box in the relevant technical room to the locations where the payphones are to be installed. Additionally, 230 V AC power shall be supplied to the locations where the payphones are to be installed.

For the ATMs to be determined during the design phase for the stations, 4 telephone cables shall be laid for each device.

Table 8.5 : Distribution of Telephone System Equipment by Area

Area Name	Service Telephone	Digital Telephone	Telecom Service Provider (External) Direct Line Telephone	Payphone	Maintenance Telephone	Emergency Telephone
Station Control Room	X	X	X			

Area Name	Service Telephone	Digital Telephone	Telecom Service Provider (External) Direct Line Telephone	Payphone	Maintenance Telephone	Emergency Telephone
Staff Room	**X**					
Medical Room	**X**					
Communications Room	**X**					
Signalling Room	**X**					
General Area				**X**		**X (IP54)**
MV / LV / Traction Power Equipment Room	**X**					
Ventilation Rooms	**X**					
Battery and UPS Room	**X**					
Electrical Panel Rooms	**X**					
Platform						**X (IP54)**
Drainage/Sewage Pump Room	**X (IP54)**					
Fire Pump Room	**X (IP54)**					
Turnstile Area	**X**					

Area Name	Service Telephone	Digital Telephone	Telecom Service Provider (External) Direct Line Telephone	Payphone	Maintenance Telephone	Emergency Telephone
PSDS	**X**					
DC Isolator Room	**X**					
Offices, Meeting Rooms		**X**				
Training Room	**X**					
Turnstile Equipment, GSM, Fibre Optic Cabinet Rooms	**X**					
Emergency Exit Staircase						**X (IP54)**
Tunnels						
Main Line Tunnels						**X (IP66)**
Switchyard Area					**X (IP66)**	
Platform End					**X***	

* If a full-height PSDS, if applicable is present, it shall have an IP54 protection rating; if not, it shall have an IP66 protection rating.

8.1.5. Digital Radio Communication System

8.1.5.1. General

The Digital Radio Communication System is designed as the primary wireless communication system providing a secure communication infrastructure for the operation, maintenance and emergency management of railway lines.

System selections within the Digital Radio Communication System may vary depending on local, geographical and technical conditions, as well as administrative/management decisions. (For example, difficulties in frequency allocation in the city where the railway system is to be built, etc.) Furthermore, depending on official, written decisions taken by the local authorities (municipalities, etc.) of the city where the railway line is being built, it may be requested that certain components of the Digital Radio Communication System (equipment related to above-ground coverage, etc.) be excluded from the scope of the construction works. Although these components are usually the responsibility of the construction contractors, they may be excluded from the scope depending on the project and the work, provided that the official and written decisions mentioned above exist.

The Digital Radio Communication System may be designed as TETRA, APCO25 Trunk or another Administration/Operator-approved Digital Radio Communication System. The selected solution shall support secure, resiliant and interoperable voice communication for operation, maintenance and emergency management of the INRAIL Line.

The Digital Radio Communication System includes, but is not limited to: base stations, a repeater subsystem, station and line-side passive equipment (RF cables, antennas, connectors, splitters, couplers, leaky cables, etc.), the switch(es) required for base station switching, handheld radios, TCC radios, the system computer and the radio recording system.

The outdoor areas (open areas) where radio coverage shall be provided are defined as follows:

- areas formed by an offset of 25 metres from the boundaries of the station excavation areas
- areas formed by an offset of 25 metres from the outer boundaries of any structures on the surface or with an exit to the surface (emergency access/ergess structures, technical buildings, etc.)

Outside the areas specified above; along the route and within a reasonable vicinity of the path taken by Administration and INRAIL Operation vehicles travelling between stations or between any station and the INRAIL Line operations centre/premises, and/or in other external areas (open areas) to be determined by the Administration, radio coverage may or may not be provided at the Administration’s discretion. If coverage is requested, the boundaries of the external area for which coverage is requested shall be clearly defined in the construction tender documents for the relevant INRAIL Line, and two-way, clear and intelligible radio communication shall be provided within the defined areas.

Radio coverage shall be provided in all areas of the INRAIL Depot and Maintenance Sites, regardless of whether they are above or below ground, in accordance with the conditions set out in this section.

The Digital Radio Communication System shall provide fully reliable internal communication throughout the entire railway line (stations, tunnels, viaducts, generator buildings, transformer buildings and all other areas) and in the open areas defined above using a system operating within the correct frequency range, with sufficient bandwidth and appropriate field strength.

End-to-end encryption shall be implemented in the system to be established to ensure security. Redundancy and hot standby shall be provided in the radio equipment to ensure the reliability of communications in the event of equipment failure.

Radio coverage shall be established at stations and along the route.

The system as a whole will be fail-safe, and redundancy shall be provided for all critical components, thereby ensuring uninterrupted communication in the event of equipment failure. The details of fail-safe and redundancy shall be determined during the design phase.

All voice and data communications shall be manageable from a central control unit, allowing for monitoring and control.

Radio coverage at the stations shall be provided by repeaters located at the stations, which will relay radio signals received from the base stations to be installed.

Should one of the redundant main base stations fail whilst the system continues to operate via the other, this situation shall be displayed as a major alarm on the TCC communications operator’s workstation, and the operator shall be alerted. Furthermore, this alarm shall be one of the major alarms sent to the SCADA system, and the Digital Radio Communication System’s main equipment failure shall be monitored in real-time.

The system to be installed and the base stations used within it shall enable individual and group calls both above ground within their own coverage area, and underground across the entire network of stations and track sections, even if the connection to the other base station and the control centre is lost.

All areas of the stations, including concourses, offices, stairwells, platforms, station entrances, emergency entrances and exits, passageways, plant rooms, communications rooms, signalling rooms and all other technical rooms (including lift and cable shafts, drainage pits, etc.), as well as along the line in open and elevated sections, on viaducts, viaduct/tunnel/covered section transitions, emergency exit shafts, tunnels, and tunnel/covered section ventiletion and plant rooms, two-way, uninterrupted, interference-free, clear, open and clearly intelligible radio

communication/intercom shall be provided with 100% coverage (min. -90 dBm). -90 dBm is the threshold value for clear and intelligible coverage but is not a sufficient condition.

It is essential that all sections of the line and the open areas described above are covered by the radio network, leaving no dead spots, and that 100% coverage is provided in a clear and intelligible manner.

The necessary calculations shall be carried out during the design phase.

Radio transmission in tunnels and passenger stations within tunnels will be achieved using leaky coaxial cable (fed from both ends) or antennas; in open sections such as bridges and viaducts, it shall be achieved using radio antennas. In particular, at the mid-points between stations within the tunnel, in blind spots and at junctions, all necessary measures (such as signal boosters, repeaters, etc.) shall be taken to ensure that the leaky cable does not cause any weaknesses in radio coverage for handheld and vehicle radios.

The leaky cable to be used in the system shall have a broadband-supporting structure. The wall mounting brackets for the leaky cable shall also be designed to be fire-resistant.

All antenna feed cables shall be waterproof, weather-resistant, low-loss, closed-cell foam dielectric type or a cable with superior properties.

All antenna cables and all antenna feed cables shall be suitable for use in underground railway systems, featuring a halogen-free and flame-retardant sheath of the type specified in. All antennas to be installed along the line shall remain outside the structural gauge of the railway line vehicles.

All connectors used in the system shall be covered with a shrink-wrap sleeve. Antennas, splitters, combiners, couplers, etc., and other passive equipment shall under no circumstances be installed within the cable tray.

The passive RF equipment to be used in the system shall be planned for easily accessible locations. In leaky cables, mounting brackets shall be designed from steel material at intervals of every 10 metres.

The Digital Radio Communication System to be designed shall be fully digital, based on an open standard, and shall be divided into five complementary sub-groups within a shared broadcast network. These groups shall be dynamically configurable and manageable. Where necessary, sub-groups can be created instantly from a central location to enable collaboration between these groups. Both voice and data communication shall be possible via these groups. For example: Two personnel from each of the operations and emergency response units can be brought together in a group on an ad-hoc basis to complete a defined task, and calls can be made

exclusively to this group; both voice and data communication can be facilitated with these units. Excluding the depot, the four (4) sub-groups and their associated channels shall consist of the following:

- Operational information channels,
- Operational radio voice channels,
- Maintenance radio voice channels,
- Emergency radio voice channels,

During the design phase, the existing channel structure within the current operation shall be examined, and a channel structure shall be established that is compatible with the existing setup.

All functions shall be easily adapted to the needs of the railway line using a screen with an intuitive menu.

Control and information signals within the Digital Radio Communication System shall be transmitted via the fibre-optic network allocated to the Digital Radio Communication System within the Transmission System. Any devices/equipment used in between shall be redundant.

Portable transceiver devices (radios) shall enable message, packet data and voice communication; during voice communication, access to and use of the device menu shall be possible without interrupting the communication. Individual calls can be made from all radios, and there shall be an address book stored in the radio's memory for these calls.

Portable transceiver devices shall be able to transmit and receive messages on all channels; they may also be programmed in accordance with profiles provided by the Administration to operate only on specific channels.

The radio shall be able to conduct normal communications even whilst in repeater mode.

During the design phase, coordination shall be established with the relevant authority to ensure compliance with the UHF bandwidth allocated to the railway line radio operation; it shall be investigated whether there are any obstacles to obtaining the necessary licence for broadcasting on the existing frequency, and it shall be confirmed that this process can be carried out during the construction phase. Provided that the system to be designed offers greater advantages, if a new frequency allocation or new frequency band is required, it shall be confirmed that these allocations can be made during the construction phase, and necessary precautions shall be taken during the design phase against potential risks.

Power calculations and drawings relating to the radio communication area of the railway line and the open areas described above, together with the reasons for equipment and cable selections, shall be prepared.

For each radio subsystem, drawings showing the locations and connections of the main stations, amplifiers, splitters and antennas shall be prepared, along with power values and calculations for coverage across all areas, particularly at termination points.

In signal level calculations for the Digital Radio Communication System, potential losses such as leaky cable losses, coaxial cable losses, insertion losses from connectors and other components, matching losses, propagation, penetration and other transmission losses, and body loss shall be included in the calculations.

Dimensions shall be provided in the drawings, and the length of each section of transmission, coaxial and all feeder cables shall be specified.

The drawings shall detail the detection points and types for each type of cable, as well as the types of end fittings.

Taking into account the handheld radios currently in use, all calculations showing the net signal strengths (dBm) obtained under the worst-case conditions for the following elements shall be provided.

- Transmitter antennas or steerable antennas in single and double-tube tunnels,
- Transmitter cables in open sections, CATV transmitter antennas or steerable antennas,
- Station antennas, transmission cables or CATV transmitting antennas,

The calculations shall include a minimum loss of 12 dB due to body shielding in handheld radios. In the calculations, the loss between the transmitter cables in tunnels and the transmission point shall be considered to be 6 dB at a distance of 6.1 m and generally 10–12 dB. The value of 6 dB typically used for 6.1 m in free-space calculations shall not be applied.

In the calculations, the geographical location of each station shall be taken into account, and factors such as battery drain in portable devices, installation irregularities and other fluctuations that may generally be encountered will be included.

In the Digital Radio Communication System, necessary measures to eliminate the effects of lightning, radio frequency interference (RFI) from all other sources, frequency encroachment by other radio users, intermodulation, cross-modulation and masking effects shall be taken into account in the design.

Where ferrite isolators, frequency-dividing filters, band-pass filters, or clipping filters are used, these shall be shown in the drawings and included in the calculations.

In addition to the above, measures to eliminate and/or minimise the masking caused by other radio users in the vicinity entering the frequency shall also be taken into account in the design.

If currently available, the existing Central Voice Recording Server shall be utilised, with the necessary revisions and additions made. Voice recordings stored on the Voice Recording Server shall be stored digitally and can be queried by date, time and channel, and subsequently listened to either via the server or via operator computers connected to the central interface server. All data streams, including voice, shall be recorded.

Within the scope of the Digital Radio Communication System, all communications made on all radio channels shall be recorded for a period of 24 hours and 30 days.

The selected train-borne digital radio communication system shall not be used for any data transmission other than radio communication. All data requiring transmission from the train to the centre, excluding signalling system data shall be carried via the “Onboard Control and Communication System (Onboard CCS)”.

The quantity of handheld radios specified in the project, along with two vehicle radios per railway vehicle (for both ends) and the associated equipment, shall be accounted for during the design phase as items to be supplied by the Construction Contractor.

The TCC shall be equipped with digital radio communication system software for monitoring and managing the system during Communication and Traffic sessions. This software shall enable the monitoring of all communications within the system, the establishment of contact with any desired user, and the performance of all administrative tasks such as grouping and authorisation.

The Digital Radio Communication System design shall be finalised through digital radio communication system coverage simulations carried out using appropriate software, taking into account the necessary equipment (antennas, coaxial and leaky cables, splitters, couplers, etc.) required to enable two-way radio communication. It shall be verified via simulations that a suitable design has been created to meet the required design criteria (100% coverage, minimum -90 dBm, etc.) shall be verified through simulations. The detailed technical specifications of the equipment used in the design shall be provided in the simulation report.

8.1.5.2. TETRA Digital Radio Communication System

In addition to the conditions specified in the 8.1.5.1. General” section for the TETRA Digital Radio Communication System, the following conditions shall also be met.

The Digital Radio Communication System shall be IP-based and compliant with ETSI standards.

The air interface protocol shall be TETRA V+D (ETSI EN300 392) or a superior standard as required by current needs.

In addition to the TETRA frequencies allocated to the operator/authority, the system infrastructure to be established shall also provide services in the 380-470 MHz band, specifically on frequency bands allocated to the municipality of the city where the railway line is to be constructed (the number of channels will be specified during the design phase), the police, security units, fire brigade, ambulance services, search and rescue, and other emergency authorities, and will cover the 380–470 MHz band.

The main repeaters shall be hot-standby with one another and shall also be supplied with backup power from at least two different base stations. Furthermore, full redundancy shall be ensured through the interconnection structure between repeaters at adjacent stations; in the event of a repeater failure at a station (low mode), the area in question shall remain within coverage.

Two-way radio communication shall be provided at all points along the route and within a reasonable vicinity where management and rail system operation vehicles travel between stations or between any station and the railway line operations centre/premises. Communication shall be ensured to be clear and distinct between operational and maintenance vehicles travelling on the surface and trains travelling along the line.

The system shall support simultaneous voice and data transmission. Individual calls (simplex/duplex), group calls, multi-group calls (broadcasting), telephone connections, short message service, priority calls, call routing, area selection, ambient listening, dynamic group allocation, call queuing on busy, emergency calls, call group recognition, dynamic group allocation, and operator call authorisation will be fully integrated into the system’s operational components. Furthermore, the system shall enable the remote loading of the aforementioned configurations onto handheld and vehicle radios.

The infrastructure to be established shall be compatible with a communication infrastructure covering the city where the railway line is located, as required. To this end, if a new Tetra Switch is required, it shall be designed with the necessary software and licences to allow for expansion to at least 16 base stations (64 channels).

Each transceiver shall have a repeater function to extend the radio coverage area.

All radio devices shall be compatible with the TETRA system.

The Digital Radio Communication System infrastructure, software and hardware shall be capable of operating as part of the Central TETRA Radio Communication System in the city where the railway line is located (if any), and shall be designed in such a way that this Central TETRA Radio Communication System can take over/control this communication system.

8.1.5.3. APCO25 Trunk Digital Radio Communication System

In addition to the conditions specified in the 8.1.5.1. General section for the APCO25 Trunk Digital Radio Communication System, the following conditions shall also be met.

The Digital Radio Communication System shall be IP-based and compliant with TIA-102 / Project 25 standards. The air interface protocol shall be APCO25 Trunk or a superior standard as required by current needs.

The infrastructure of the APCO25 system to be established shall be designed to cover the relevant approved frequency range, providing service not only on the operational frequencies allocated to the operator/Authority but also, where required and technically compatible, on frequency bands allocated to the municipal, police, security, fire service, ambulances, search and rescue, and other emergency authorities. The exact frequency bands, channel numbers and interoperability requirements shall be determined during the design phase and submitted for approval.

The main repeaters shall be hot-standby with one another and shall also be supplied with a backup from at least two different base stations. Furthermore, full redundancy shall be ensured through the connection structure established between repeaters at adjacent stations along the railway route ; in the event of a repeater failure at a station (low mode), this shall prevent train radios in that area from being left out of coverage.

Communication shall be ensured to be clear and distinct from within trains travelling along the line.

The system shall support simultaneous voice and data transmission. The following services shall be supported by the system:

- Individual calls,
- Group calls,
- Multi-group calls (broadcasting),
- Recording,
- Telephone connection,
- Text messaging service,
- Scheduled message delivery,
- Priority call,
- Interruptible priority call,
- Area selection,
- Ambience listening,

- Dynamic group allocation,
- Queueing on busy,
- Emergency call,
- Call group recognition,
- Dispatcher call authorisation

Furthermore, the system shall enable the remote loading of the above configurations onto handheld and vehicle radios.

The infrastructure to be established shall be compatible with a communication infrastructure covering the entire city where the railway line is to be built, as required. In terms of expansion capacity, the system shall be capable of scaling up to at least 16 base stations (64 channels) and shall be supplied with all software and licences.

Train radios shall be equipped with a repeater function to extend the coverage area.

All radio devices shall be compatible with the APCO25 Trunk system to be installed.

If there is a communication system in the city where the system is installed that centrally manages the city's public safety communication systems, a management interface software connection shall be established between this centre and the system to be installed.

8.1.6. Public Address System

A public address system shall be designed for stations within the railway network to provide information to passengers and staff and to broadcast voice evacuation messages in emergencies.

The Public Address System shall provide electro-acoustic, industrially controlled, open, reliable, noise-free live and recorded announcements; It will be designed to enable authorised personnel at the TCC, Station Control Rooms (SOR), and Depot Control Room (DOR) to communicate seamlessly, clearly, and reliably with staff at passenger stations, passengers, and personnel at the Depot and Maintenance Area.

Standards applicable to the system (including but not limited to);

TS EN 54-4, Fire Detection and Alarm Systems – Part 4: Power supply equipment

TS EN 54-14, Fire Detection and Alarm Systems – Part 14: Guidance on planning, design, installation, commissioning, operation and maintenance

TS EN 54-16, Fire Detection and Alarm Systems – Part 16: Audible alarm control and indicating equipment

TS EN 54-24, Fire Detection and Alarm Systems – Part 24: Audible alarm system components – Loudspeakers

TS EN 54-32, Fire Detection and Alarm Systems – Part 32: Methods for the planning, design, installation, commissioning, operation and maintenance of audible alarm systems

BS 5839-8, Fire detection and fire alarm systems for buildings. Code of practice for the design, installation, commissioning and maintenance of public address systems

TS EN 50849, Public address systems for emergency situations

TS EN 60268, Audio system equipment

The system design and manufacture shall fully comply with the General System Requirements and System Technical Requirements of TS EN 50849.

Compatibility with architectural design criteria shall be taken into account when selecting public address equipment.

The audio and digital control signals of the public address equipment shall be transmitted via the transmission system infrastructure.

The Public Address System shall include, but is not limited to: speakers located in passenger-accessible areas, technical corridors and staff areas; an induction loop; noise microphones; announcement consoles with keypads and flexible-neck microphones, capable of making live and recorded announcements, located in the TCC, SOR and DOR rooms; and controllers and amplifiers located in the communication rooms.

Via the announcement consoles, recorded and live announcements shall be made to all stations and selected areas within stations, and the status of the announcement system at stations shall be continuously monitored.

Local announcement consoles shall not be installed on platforms on new railway lines. However, on railway lines that are extensions or continuations of an existing railway line, local announcement consoles shall be installed on platforms in accordance with the equipment on the existing line.

Announcement System desktop announcement consoles shall be located not only in the TCC but also at the locations specified below.

- A desktop announcement console for the Station Control Room (SOR) at each passenger station
- A wall-mounted announcement console for local announcements in the centre of each platform at stations (where such a system has been installed on an existing railway line, it shall be used on railway lines constructed as extensions of that line)

Broadcasts from the public address consoles and/or workstations shall be made as follows:

From the TCC to the following areas;

- Each individual platform at a selected station,
- All platforms at a selected station at the same time,
- Each individual concourse at a selected station,
- All concourses at a selected station,
- Each individual passenger circulation area at a selected station (mezzanine levels, etc.),
- All passenger circulation areas at a selected station (including mezzanine levels and similar sections),
- All technical area corridors at a selected station (including SOR, Staff Rest Rooms and noisy rooms),
- Concourses, passenger circulation areas and all platforms at a selected station simultaneously,
- All platforms simultaneously at a selected group of stations
- At a selected group of stations, the concourse, passenger circulation areas and all platforms,
- At a selected group of stations, all technical areas simultaneously,
- All platforms at all stations simultaneously,
- At all stations simultaneously: concourses and all platforms,
- All areas of a selected station or group of stations,
- Separately and simultaneously in areas where staff are present within buildings at the Depot and Maintenance Site.
- On driver-operated railway lines, to driver's cabs separately and simultaneously.

From the Station Control Room (SOR) at each station to the following areas;

- To each platform at the station individually,

- All platforms at the station at the same time,
- Each concourse at the station separately,
- All concourses at the station simultaneously,
- Each passenger circulation area at the station (mezzanine levels, etc.),
- All passenger circulation areas at the station (mezzanine levels, etc.),
- All technical areas at the station simultaneously,
- To all concourses and all platforms at the station simultaneously,
- To all areas of the station simultaneously,
- On driver-operated railway lines, to driver cabins separately and simultaneously.

If available, from the wall-mounted announcement console on each platform to the following areas;

- Only to their own platform,
- To the TCC and SOR console speakers (intercom-style)

The announcement priority sequence is as follows, except under Emergency Scenario conditions:

- Any announcements made via the wall-mounted announcement consoles on each platform
- Announcements made in the Station Control Room (SOR)
- Announcements made from the Traffic Control Centre (TCC)

Desktop microphones shall be LCD-screen and touchscreen.

The desktop announcement console shall have the following features:

- Flexible-neck microphone
- Push-to-talk button
- Built-in speaker
- Freely programmable selection buttons
- Activation indicator for each button
- Transparent key cover to prevent accidental key presses
- A key combination or similar measure will be implemented to prevent unintended broadcasting.

The operator console shall consist of a push-button voice input, high-quality, noise-compensated microphone that provides a flawless mix of bass and treble sounds and shall also include a digital gong and alarm tone generator (single, double, triple tone sequences).

While at least 16 selection buttons are required for recorded announcements, the exact number shall be determined during the design phase based on the number of recorded announcements and announcement zones.

Live or recorded announcements made by the TCC shall be heard via the Station Control Room (SOR) console or a separate loudspeaker. The TCC Operator shall be able to add or remove announcements via the communication session, in addition to the recorded announcements. In the announcement system, a key combination or similar measure shall be implemented to prevent the Station Manager from inadvertently broadcasting emergency announcements via the console.

The wall-mounted announcement console shall have the following features:

- Handheld push-to-talk microphone
- Built-in speaker
- Freely programmable selection buttons
    - Activation indicator for each button
    - Key-locked cover to prevent unauthorised use

The public address system shall be continuously monitored via the SCADA system and, when required, one of the pre-defined public address scenarios for emergency situations shall be activated via the SCADA system. The audio and digital control signals from the public address equipment shall be transmitted via the transmission system infrastructure.

Suitability calculations shall be carried out for speaker placements to ensure an adequate dB level for emergency announcements.

The system shall be designed such that the sound level is at least 10 dB above the average ambient sound level. The design shall comply with BYKHY standards. The sound level shall be analysed at a height of 1.5 metres above ground level.

The sound pressure level of the loudspeakers shall be higher than the ambient noise level. The minimum noise levels for the system design, by zone, are as follows:

- 55 dB for speakers on the ticket hall level,
- 80 dB for platform-level speakers,
- 75 dB for speakers on the staircases,
- 55 dB for speakers in technical areas,

- 55 dB for the integration level

shall be selected.

All loudspeakers;

- Designed for use in emergency public address systems, with metal enclosures (self-contained plastic enclosures only for suspended ceiling types), designed for high-quality speech and music broadcast; shall be EN 54-24 certified and compliant with the BS 5839-8 standard.
- In accordance with IEC 268-5 Power Handling Capacity (PHC) standards, they shall be designed to withstand operation at their nominal power for 100 hours.
- It shall feature internal protection to ensure that damage to the speaker caused by fire does not result in a fault in the connected circuit.
- It shall feature a ceramic screw-type terminal block, a thermal fuse and high-temperature-resistant connections.
- It shall be of a high-efficiency type and will be powered from a standard 100 V line.
- The power transformer shall be connected at the 50% tap to allow the output power to be increased if required at a later date.
- The Sound Pressure Level at nominal power shall provide a minimum value of 94 dB (1 kHz, 1 m).
- The frequency conversion shall not be less than 75 Hz.
- Suspended ceiling-type loudspeakers in the station and other buildings shall have a minimum IP21 rating.
- Projector-type loudspeakers in stations and other buildings shall have a minimum IP65 rating.
- Speakers of other types in stations and other buildings shall have a minimum IP54 rating.

Projector-type loudspeakers in open areas shall have a minimum IP66 rating.

The system shall be designed to allow separate and specific announcements to be made from the main call stations to designated areas (zones).

Zoning shall be implemented such that the general and technical areas of each platform shall be called or addressed independently and separately from any other zone(s), either together or completely separately.

The system shall have the capability to allow live or pre-recorded announcements to be made to a single zone or any combination of zones.

Table 8.6 : Example Zoning for the Announcement System

Locations	Platform 1	Platform 2	Ticket Hall	Technical Areas	Station Evacuation Exits
Zone Number	1	2	3	4	All

The power required by the zones for broadcasting, measured in 'Watts', shall be supplied by amplifiers connected to the central unit. The output power of the amplifiers shall be calculated. No speaker shall be connected to any amplifier at 100% capacity, and under normal operating conditions, the output power shall never reach 100%. A minimum of 10% reserve capacity shall be left in the capacity of each individual amplifier. A total of 20% reserve capacity shall be left in each system cabinet.

The system architecture shall be designed so that announcements shall be made to all zones even in the event of a single-point failure, based on all equipment within the system (speakers, amplifiers or control units, etc.), and shall possess all the features specified in the EN 50849 standard, additional design conditions, and amplifier and line redundancy.

Two separate 100V lines shall be provided for each announcement zone within the system. A dual announcement line system shall be installed in the areas covered by the project; the speakers in each area shall be connected to two separate lines in a staggered configuration, and the lines within the same area shall be connected to different amplifiers. This will ensure that announcements shall still be made to the relevant zone even in the event of an amplifier or line failure. Line termination units shall be installed at the ends of the lines.

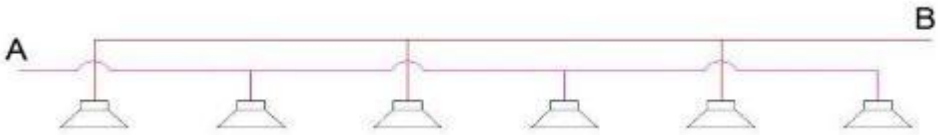


Figure 8.1 : Schematic Diagram of the Public Address System

Speakers on station platforms and concourses shall be fitted with fire-resistant domes in areas with suspended ceilings; they shall be easily removable and installable, as accessible as possible for maintenance purposes, and mounted either suspended from the ceiling or recessed. In areas where access is difficult, such as above staircases, they shall be installed at easily accessible points. In areas without suspended ceilings and in technical spaces, they may be selected in a directional (projection) type. In all areas, the selected loudspeakers shall be in harmony with the architecture. The loudspeakers shall be connected to the lines via connectors and installed with flanges. The protection ratings for the loudspeakers shall be at least IP21 for suspended ceiling types and IP65 for projection types.

The cables to be used in the public address system shall be FE180 PH120. The public address equipment shall fully comply with the requirements of NFPA 130, EN 54 and EN 60268 regarding fire alarms.

Table 8.7 : Distribution of Public Address System Equipment by Area

Area Name	System Panel/ Cabinet	Public Address Console	Speaker	Noise Microphone
Station Control Room (SOR)		X		
Staff Room, Staff Changing Room			X	
Communications Room	X			
Toilet, Baby Care Room, First Aid Room			X	
Common Area			X	X
Technical Area Corridors			X	
Emergency Exit Routes			X	
Staircase & Escalator Area			X	
Platform			X	X
Turnstile Area			X	
Driver's Cab*			X	

*For railway lines where the signalling system is designed to be driver-operated. The zone shall be designed separately.

Speakers shall also be installed within the technical area corridors in areas such as the MV/LV/Traction Power Equipment Room, Tunnel Ventilation Fan Room and EXF Fan Room, which are large in volume and have high noise levels. Where there is a technical area beneath the platform, speakers shall be installed in these areas and included within the technical area corridors.

Speakers located in the connecting corridors between platforms shall be divided into two sections, with each section included in the Platform 1 and Platform 2 lines.

Emergency exit zones in stations and tunnels shall be included in the public address system, and announcements shall be made at these points.

Noise microphones shall be installed at each platform and on the ticket hall level in stations to adjust the sound level within the system. Thanks to the noise microphones, the public address equipment shall be able to adjust itself to the ambient noise level in each area. All necessary calculations shall be carried out to ensure that announcements are at a clear and audible volume, particularly in noisy environments, during train arrivals and departures on platform areas, and in all areas with high passenger traffic.

An announcement workstation and a microphone-equipped announcement console shall be located in the Station Control Room (SOR) and the Depot Control Room (DOR). Recorded and live announcements shall also be audible via the speakers of the workstation or the announcement console.

The design of the public address system shall be verified through simulation using sound simulation software. In the simulations, the acoustic properties (particularly sound, reverberation, reflection, sound absorption capacity, differences in delay time, and feedback) of all structures and areas where the public address system is installed (stations, TCC, railway line administrative building and its ancillary facilities, etc.) shall be taken into account. The software to be used shall be capable of simulating the acoustic responses of the equipment used in the design exactly; similarly, the existing architectural structure shall be modelled as closely as possible to reality so that the acoustic performance of the design shall be measured with high precision. Materials used on the floor, ceiling, side walls and all surfaces with which sound waves may interact (concrete, galvanised steel, steel, etc.) shall be definable within the programme. Mathematical models containing the frequency-dependent absorption/reflection coefficients required for acoustic calculations for all materials, as well as dynamic values such as the frequency-dependent sound pressure levels and dispersion angles of the selected loudspeakers, shall be available in the programme's database. By defining the potential areas where listeners shall be located and the listener's ear height in the created design, the sound pressure level and intelligibility of the sound emitted from the loudspeakers on the target audience should be measurable.

For each simulated station/building storey: direct sound pressure level (Direct SPL, in dB), total sound pressure level (Total SPL, in dB), RASTI (Rapid Speech Transmission Index), ALcons (as a percentage), arrival time (in milliseconds), noise (in dB), and reverberation time (in seconds) shall be reported. The detailed technical specifications of the equipment used in the design shall be provided in the simulation report.

Using the public address system infrastructure, it shall also be possible to broadcast music from the TCC to any desired area.

To ensure intelligible broadcasts, announcements and music broadcasts shall be made in public areas where ambient noise exceeds 10 dB.

Sound level, treble, bass and intensity shall be adjusted throughout the entire system. This shall ensure that the broadcast is as desired.

Acoustic calculations shall be carried out as part of the measures to be taken to ensure intelligibility (e.g. sound-absorbing materials).

The design shall ensure that the minimum Speech Transmission Index (STI) value is at least 0.58 on station platforms and in all other public areas, and at least 0.50 in areas without passengers.

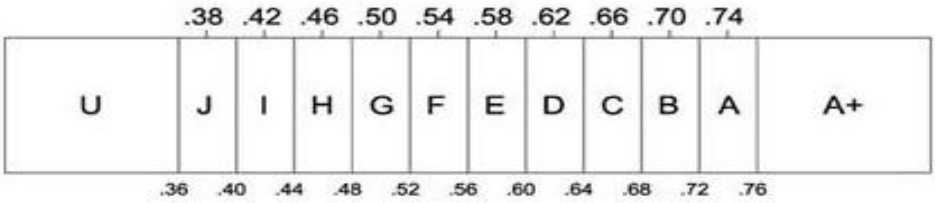


Figure 8.2 : Minimum Speech Transmission Index (STI) values

The public address system shall be continuously monitored via the SCADA system and, when required, one of the pre-defined public address scenarios for emergency situations shall be activated via the SCADA system.

It shall be capable of triggering different announcement messages in multiple ways during emergency scenarios.

Alarms from the public address system shall be transmitted as data to the SCADA system.

There shall be an Ethernet or similar physical interface between the public address system and the signalling system. It shall be capable of generating pre-recorded public address announcements as required during operations to meet minimum triggering requirements (e.g. information on a train entering the platform, the number of carriages in the arriving train, etc.).

There shall also be an interface between the public address system and the clock system, as well as the fire detection and alarm system.

The public address system shall include a Main Control Unit to manage the system and a Recording Unit to serve as digital voice memory. The system’s main unit shall have a flexible

structure, capable of expanding via cards from 4 zones/2 loops up to 44 zones/22 loops. Multiple main units shall also be able to be connected in a loop or zone configuration. The main units shall have a direct SFP port. This shall allow for connection to the main unit via SFP without the need for additional converters to connect the fibre. The Emergency Announcement System shall have its own graphical monitoring and management software, which shall be provided by the manufacturer.

The following functions shall be provided via the system's software:

- It shall include graphical maps of all locations and sub-locations.
- There shall be different user authorisation levels.
- Relevant interfaces shall be displayed according to user authorisation and location.
- The announcement zones for the relevant location shall be selected using a graphical map or buttons.
- Live and recorded announcements shall be made to the relevant location and sub-locations.
- Live and recorded announcements shall be heard via the operator workstation.
- Music broadcasts shall be made to the desired location and sub-locations from the TCC.
- It shall be possible to schedule activities such as the automatic playback of recorded announcements or adjusting the volume of background music during evening hours.
- Remote monitoring and configuration of all main units can be carried out easily and effectively via the network, and information regarding the system status shall be displayed.
- It shall monitor the status of all hardware in the system, report status changes and store fault messages within the system.
- Event logs for all alarms and triggers from all locations shall 0be maintained and displayed in real-time on the interface.
- All licences for the hardware and software to be used within the system shall have a 20% reserve capacity.

8.1.6.1. Audio Frequency Induction Loop (AFIL)

Audio Frequency Induction Loop (AFIL) shall be installed in the locations listed below for people with hearing difficulties.

- On platforms
- In lifts
- In the kiosk areas at ticket purchase points

The public address system shall enable announcements broadcast via this induction loop system to be heard by people with hearing difficulties and those using hearing aids.

Induction loops shall be designed to cover an area of 30 m² for each loop.

Regarding the creation of 30 m² audible areas on platforms: 2 units shall be installed on platforms 0–100 metres in length, 3 units on platforms 101–150 metres in length, and 4 units on platforms 151–200 metres in length, thereby creating 30 m² audible areas. The system amplifier(s) shall be installed in a suitable room or communications room. A connection shall be made to the platform-type induction loop amplifier using the audio output from the existing public address system. The cables to be used in the induction loop system shall be N2XH FE180, twin-core cables.

The system shall be designed to provide a coverage area that allows passengers using hearing aids to receive the broadcast from a distance of at least 1 metre from the device. The square metres of the areas shall be taken into account during the design.

Locations with Audio Frequency Induction Loops shall be clearly and unambiguously marked with signs.

The audio frequency induction loop system shall comply with all requirements of the BS 7594 and TS EN 60118-4/A1 standards.

The recommended field strength for communication with the long-term average level of the speech signal is ±3dB 0.1 amp/metre, measured at a height of 1.2 metres above the floor. However, natural peaks in speech can exceed the average value by up to four times; therefore, the maximum field strength produced by the loop shall be sufficient to meet these requirements (0.4 amp/metre +12dB). The field strength value shall be selected based on sensitivity tests for typical hearing aids and a sufficient (magnetic) signal-to-noise ratio. The background level of magnetic noise shall be measured prior to installation and included in the calculations. The recommended frequency range is 100–5000 Hz. (Relative to the level at 1000 Hz ± 3 dB)

The standardised field strength value shall be set such that the signal from the induction loop is as loud as the sound a person using a hearing aid in acoustic coupling mode would hear when listening to another person speaking.

The points to be considered in the design of the induction loop are listed below;

- The background magnetic noise level shall be calculated.
- The design shall be carried out once the loop dimensions and locations have been determined.
- The average current in a single-row loop shall be calculated.
- The average current in a single-row loop shall be calculated.

- The maximum current in a single-row loop shall be calculated.
- The total cable length for the single-row loop shall be calculated.
- The cable gauge shall be determined in order to calculate a resistance value compatible with the amplifier specifications.
- The amplifier power ratio shall be calculated.
- The input level and amplifier gain control shall be determined to verify the operating level.

The loop field strength and current shall be verified.

8.1.7. Closed-Circuit Television System (CCTV)

8.1.7.1. General

The CCTV system is designed to monitor all public areas of stations (turnstile zones, platform areas, etc.) and certain non-public sections (technical spaces, emergency exit structures, etc.) to ensure the live monitoring, transmission, recording, storage and management of high-resolution, full-colour, clear, delay-free, flicker-free and interference-free images that enable the identification of individuals even under emergency lighting conditions. Stations shall be designed so that there are no blind spots, based on CCTV coverage simulations carried out in passenger circulation areas, and cameras shall be installed to ensure clear and intelligible monitoring of passenger movements with 100% uninterrupted coverage from the entrance to the platform (including the platform and connecting tunnels).

The entire system architecture shall be designed to operate over an IP Ethernet network. All equipment to be used shall be selected to be compatible with internal IP Ethernet communication.

Footage from all areas where the camera system is installed shall be viewable and manageable in real-time and via recordings from the TCC and the relevant local operations/control/security room (SOR, DOR, etc.).

The quantities and specifications of the workstations and monitors to be used in the CCTV system are provided in the section “7.6.2. Control/Monitoring Areas (TCC, SOR, DOR, etc.) Requirements”.

In the event of a communication failure between the TCC and any station/site, the operator in the local operations/control/security room (SOR, DOR, etc.) at the relevant location shall be able to carry out control and management activities for all cameras and auxiliary equipment located at the relevant station/building.

The network infrastructure allocated to the CCTV system on the Transmission System shall be used for the transmission of images. Bandwidth calculations shall be performed for the entire system to determine the required capacity.

The system shall feature advanced image processing algorithms and intelligent video analytics capabilities.

Video analytics techniques:

- Motion detection
- Camera tampering detection
- Audio detection
- Object counting
- Adaptive motion detection
- Object disappearance
- Abandoned object
- Automatic zoom and tracking (on pan-tilt cameras)

shall include these features, and alarm information shall be automatically received from cameras where at least two of these features are used simultaneously (the exact number and which features are used shall be determined according to the project).

All devices in the system shall operate synchronously by updating their own date and time information via the central time system.

All equipment and materials used in the design shall be original components manufactured and sold by the original manufacturer. All products shall have been thoroughly tested and proven in real-world use.

The CCTV system shall meet the requirements for coverage, clarity and sharpness, and coverage areas shall be demonstrated through projects, simulations and calculations, taking into account potential conflicts with other equipment within the station (passenger information screens, passenger information boards, clocks, directional signs, etc. other signs and equipment) and shall be demonstrated through designs, simulations and calculations to ensure they are not affected by such overlaps.

The information to be provided shall include details of the horizontal and vertical dimensions (as a percentage of the monitor dimensions) of an average-sized person (1.7 m) as they would appear on operator monitors, for distances ranging from 10 metres to 40 metres in 10-metre increments. Coverage areas shall be detailed via simulation in accordance with the Rotakin Standard. A 50%

recognition rate shall be ensured in areas requiring particular attention for passenger safety, such as turnstiles, ATMs and ticket machines.

The system shall operate on a TCP/IP basis. Furthermore, the system shall be designed using a multicast architecture to utilise bandwidth efficiently whilst broadcasting to multiple locations.

All hardware belonging to the CCTV system shall be powered by an uninterruptible power supply (UPS) allocated to the Communication and Control Systems.

8.1.7.2. Standards

The CCTV system design shall comply with the following standards:

- TS EN 62676 Series, Video control systems for use in security applications
- TS EN 62676-1, System requirements
- TS EN 62676-2, Video transmission protocols
- TS EN 62676-3, Analogue and digital video interfaces
- TS EN 62676-4, Application rules

8.1.7.3. Camera Positions

The system shall be designed to enable visual monitoring of stations and other locations.

Passenger circulation areas to be covered without blind spots are as follows:

- Platforms and connecting passages,
- Ticket halls and mezzanines,
- Connecting corridors,
- Escalators and moving walkways (cameras shall be positioned to face the direction of passenger flow. An additional camera shall be included in the design for escalators longer than 25 metres.)
- The doors of all lifts, including those at street level,
- The interiors of all lift cabins, including those at street level,
- All station entrances (from the outside), including street level,

The areas requiring camera coverage outside of these are as follows:

- Entrance doors to the technical area corridor (from the corridor area),
- Entrance doors to the Station Control Room (SOR),
- MV/LV/Traction Power Equipment Rooms (MV switchgear, transformers, etc.),

- Emergency exit hatches (at street level),

In other areas such as administrative buildings located outside the station and its ancillary facilities;

- Administrative buildings (internal and external security),
- TCC entrance,
- Special areas (main entrances, emergency exits)
- Areas such as inside/outside the transformer building and inside/outside the generator building,
- Entry/exit points from the tunnel to the viaduct
- Cameras capable of providing appropriate imaging according to ambient lighting conditions shall be installed at the ends of the platforms (facing towards the tunnel) to monitor passenger evacuation situations.

The position and mounting details of each camera shall be determined during the design phase using planning and simulation software and submitted for approval by the Authority. These reports shall include details such as the cameras' lens specifications, field of view, and effective viewing distances.

Equipment belonging to other systems (Passenger Information System screens, signage, etc.) and their locations shall be taken into account during the design phase.

The scope of the CCTV system shall be determined in accordance with the TS EN 62676-4 standard.

There shall be one pan-tilt-zoom (PTZ) camera at the centre of each platform and in each concourse area. Additionally, there shall be a pan-tilt-zoom (PTZ) camera at a vantage point on the station concourse for general surveillance purposes.

The pan-tilt-zoom (PTZ) cameras shall be used for zooming and inspection purposes and shall not be included in the coverage calculations/simulations.

8.1.7.4. Control and Monitoring Centres

Control and monitoring centres will be located at the following sites, in addition to the Depot Control Room (DOR):

- Traffic Control Centre (TCC)
- Station Control Room (SOR)
- Security Structures (Guardhouse, etc.) (if applicable)

- Security Monitoring Centre (GİM)

The required number of video feeds from these centres shall be viewed at any time, in any sequence and at any resolution, clearly and without any interruption, freezing or interference.

The design and specifications of these centres shall be as follows:

- All cameras located on the railway line shall be viewable by operators via Video Wall units installed within the TCC.
- Operators at the TCC shall be able to view live and recorded footage from selected cameras at any location, at any time, in any sequence and at any resolution, on the desired screen, using multi-purpose workstations, monitors and the camera control console.
- Two cameras from each platform shall be recorded on the recording device at the TCC.
- Independently of the TCC Video Recording Device, a Video Recording Device with 20% redundancy and sufficient capacity shall be installed at each station.
- Station Control Rooms shall be equipped with monitors, a multi-purpose workstation and a camera control console to enable live and recorded viewing of footage from all cameras located at the station.
- In security structures (such as guardhouses), monitors, a multi-purpose workstation and a camera control console shall be provided to enable the security guard to view live and recorded footage from all cameras in their designated area.

8.1.7.5. Bandwidth and Recording Durations

All cameras in the system shall be viewable both locally and from the TCC, both live and from recordings.

Recordings shall be stored locally for 30 days at each independent location (station, TCC, etc.) and shall be accessible via the transmission infrastructure from the TCC.

All live viewing and recordings shall be in H.265 or higher encoding formats.

The technical specifications required for live monitoring and recording, with variable bit rate settings depending on camera type, are as follows:

Table 8.8 : Minimum Technical Values for Camera Recording

Camera Type	Stream	Resolution	FPS	Quality
Fixed Camera (Full HD)	1	1920x1080	25	Good
Moving Camera (Full HD)	1	1920x1080	25	Good

To reduce the system load when viewing multiple camera feeds on the same screen, the system shall switch to the second and third video streams depending on the number of cameras displayed.

The required values for other video streams are as follows:

Table 8.9 : Minimum Technical Specifications for The Second And Third Video Streams

Camera Type	Stream	Resolution	Stream	Resolution	FPS	Quality
Fixed Camera (Full HD)	2	1280x720	3	640x360	25	Medium
Moving Camera (Full HD)	2	1280x720	3	640x360	25	Medium

The specified bandwidths are the minimum values to be taken into account during system design.

8.1.7.6. Network and Transmission Structure

All switches used in the system shall be PoE-enabled and have sufficient capacity to meet the power requirements of the cameras. External PoE injector solutions shall not be used.

Where the distance between the cabinet and the cameras does not exceed 90 metres, the camera cables shall be Cat6 S/FTP LSZH.

Where the distance between the cabinet and the cameras exceeds 90 metres, the cameras in the relevant area shall be housed in an IP54-rated switch cabinet located in a suitable technical room. Communication between this cabinet and the main cabinet shall be provided via single-mode fibre optic cables. The fibre optic cables shall have a one-to-one redundant fibre count. A power supply cable shall also be installed for the cameras where fibre optic cables are installed.

Communication between the main cabinet and the switch cabinets shall be in a redundant (ring or star) configuration.

Fibre optic cables shall be terminated in standard rack-mounted patch panels.

All fibre termination connectors on the patch panels shall be of the APC type.

Cables exiting the patch panels shall be connected to the switches' GBIC modules using standard-compliant patch cables.

The system's network communication infrastructure (ports, bandwidth, etc.) shall be designed to include a 20% reserve capacity at each aggregation point. The reserve capacity shall not be concentrated in a single location.

It shall have the necessary capabilities (hardware, software, licences, etc.) to be monitored from a different centre outside the line where the system is installed (wide area network – WAN).

8.1.7.7. Control Consoles

There shall be a control console compatible with workstations and cameras to control the pan-tilt-zoom (PTZ) cameras within the system.

This control console shall operate in a manner compatible with the workstation and management software via a USB port or an Ethernet network.

The control priority order for the PTZ cameras shall be as follows:

- Traffic Control Centre (TCC) operator
- Station Control Room (SOR) operator

8.1.7.8. Cameras

All fixed and pan-tilt cameras shall have the following common features:

- They shall be IP-based and support PoE (Power over Ethernet).
- They shall feature high-sensitivity true Day/Night (ICR) functionality.
- They shall offer an adjustable Wide Dynamic Range (WDR) or High Dynamic Range (HDR) feature exceeding 100 dB in accordance with IEC 62676 standards.
- It shall utilise 3D Digital Noise Reduction (3D-DNR) techniques to reduce visual noise in low-light conditions.
- It shall be capable of generating video streams in H.265 High Profile and MJPEG formats.
- It shall be able to provide video streams in up to three different resolutions simultaneously.
- It shall be capable of encoding in both Constant Bit Rate (CBR) and Variable Bit Rate (VBR) settings.
- It shall be capable of transmission in both Unicast and Multicast modes.
- Cameras to be installed on platforms in external environments and on railway lines without full-height PSDS, if applicable shall have an IP66 protection rating; all other cameras to be installed in internal environments and cameras to be installed on

platforms on railway lines with full-height PSDS, if applicable shall have an IP54 protection rating.

- Cameras at risk of impact (such as those installed in lift cabins, etc.) shall comply with the IEC 62262 IK10 standard.
- The open architecture shall be compatible with the ONVIF Profile S standard. It shall also support ONVIF event commands such as tamper alarm, motion alarm and fan failure.
- A standard web browser interface shall be provided for remote management and camera parameter configuration.
- Each camera shall have a unique code consisting of letters and numbers that identifies its location (station, etc.) and zone (platform, concourse, technical area, etc.).
- The cameras shall operate synchronously by updating their own date and time information via the central time system.
- The camera identification code and date and time information shall be displayed automatically during live and recorded viewings.
- Cameras located outdoors shall be vandal-proof, resistant to sunlight, rain and freezing temperatures, and shall provide a clear, uninterrupted image even when exposed to these conditions.

8.1.7.9. Fixed Cameras

The main types of fixed cameras to be used in the design, without limitation, shall include: ½.8" Day & Night Colour Camera with 1920 x 1080 resolution, ½.8" Day & Night Colour Camera with 2048 x 1536 resolution, and IP External Mini Dome-Type Night Vision Camera (minimum 2 MP).

Some of the general features of the fixed cameras are listed below:

- The video compression formats shall be H.265, H.264, and MJPEG; the H.265 encoding shall support the resolutions specified in the preceding paragraph and shall be capable of delivering 30 FPS (frames per second) at these resolutions.
- Fixed dome cameras shall be used for indoor environments, and bullet-type cameras for outdoor environments.

In addition to the above, the other technical specifications for fixed cameras shall be determined according to applicable AYGM/Administration requirements for urban commuter/mainline railway systems, Project-specific security requirements and the environmental conditions of the INRAIL Line.

The cameras shall be capable of performing at least four of the analyses listed below.

- Motion detection

- Camera tampering detection
- Sound detection
- Object counting
- Adaptive motion detection
- Object disappearance
- Abandoned object

8.1.7.10. Moving cameras

The technical specifications of moving cameras As specified in the “Closed-Circuit Television System (CCTV)” section of AYGM’s “Technical Specifications for the Construction of Urban Rail and Cable-Based Public Transport Systems – Metro/HRS”, these will be taken into account in the design.

8.1.7.11. Recording Servers and Storage Units

The technical specifications for Recording Servers and Storage Units shall be determined according to applicable AYGM/Administration requirements, required retention periods, cybersecurity requirements, CCTV capacity calculations and the environmental conditions of the INRAIL Line.

8.1.7.12. Interface and Integration

Alarms from the CCTV system shall be transmitted as data to the SCADA system.

An interface shall exist between the CCTV system and the clock system.

In the event of interaction with push-to-talk emergency telephones located in passenger areas, the images from fixed and/or mobile cameras in the relevant area shall be automatically displayed to the operator.

When an alarm is received from the access control system due to a door being forced open or an unauthorised entry attempt, camera footage from the relevant area where the alarm was triggered or the nearest area shall be automatically displayed to the operator.

The necessary infrastructure shall be established and an interface provided to connect the system to the CCTV backbone at the TCC, extending to the nearest existing fibre-optic infrastructure.

8.1.7.13. Event Logs and Licensing

All event logs generated by the system shall be retained in event log files for a minimum of 3 months, along with date and time information.

- The software to be used shall allow the creation of users with different levels of authorisation. All configurations shall only be carried out by authorised users.
- The software shall include a feature for creating and viewing graphical maps.
- The graphic map shall be designed to include a general map showing the entire station/hub, with all areas where the camera system is located—such as platforms, concourse levels, and entrances/exits—clearly highlighted.
- The maps shall be created using 2D graphics rendered with perspective using appropriate software. The station graphics shall 0be in 3D.
- Camera icons and their locations shall be displayed on the 3D map of the workstations.
- The software shall be capable of accommodating the addition of further cameras.
- The interface shall allow users to create customised display layouts—such as 3x3, 4x4 or 5x5—and view selected cameras automatically, manually or in sequence.
- Operators shall be able to easily select the cameras they wish to monitor using the keyboard and mouse and instantly display them on the desired monitor in the desired layout.
- During live monitoring, recordings shall be viewed by quickly rewinding based on date, time, alarms and events (motion, analysis, etc.) at any desired moment.
- The interface shall visually display the equipment codes, locations and status information (active, faulty, etc.) of all cameras.
- The IP addresses of all cameras shall be displayed when the mouse is hovered over them or when they are clicked on the interface.
- The software enables the operation and management of all fixed and pan-tilt cameras. Pan-tilt cameras shall be controlled using a keyboard, mouse and control console.
- Selected recordings shall be quickly transferred via the software as video files in H.264/H.265 compression format to USB sticks, memory cards and DVDs.
- Recorded footage shall be viewed using free decoders without the need for a proprietary decoder from any company.
- It shall be possible to extract still images from the recordings.
- In the event of faults affecting any equipment in the system (cameras, servers, recording units, etc.) or interruptions to recordings, visual and/or audible alerts shall be displayed on both local and central operator screens.
- Faults shall be classified by type and recorded in the event logs along with the equipment name, date and time details.

- The software shall feature both Turkish and English user interfaces. Should Turkish language support not be available, language files shall be obtained from the manufacturer and translated to ensure the user interface is displayed in Turkish.
- In the case of user/client-based licensing, a number of spare licences equivalent to 25% more than the total number of users (across all operators) shall be provided.
- In the case of camera-based licensing, a number of spare licences equivalent to 15% more than the location-based number of cameras shall be provided.
- All other software and licences shall be planned with a 20% buffer to allow for expansion and shall be implemented accordingly.

8.1.7.14. Security and Monitoring Centre (SMC)

The Security Monitoring Centre is a structure established as an integral part of the CCTV system for the purpose of monitoring security cameras on a rail system line and/or lines from a single central location.

For a line to be constructed as an extension to an existing rail system line currently operated by the company, which already has a Security Centre, communication shall be established with the TCC to transmit images to the existing Security Centre as well.

A GIS (Geographic Information System) map shall be used in the Security Centre to view the main line and its surroundings. In the Security Control Centre, the locations of radio users (staff and maintenance vehicles) in one, several or all groups selected on the map shall be tracked using the GPS features of their radios; the radio user's code shall be displayed on the line screen; and communication with the relevant radio user shall be established by clicking on them. In this context, the Security Control Centre room shall be equipped with a video wall screen for camera feeds and the line map.

The contractor shall provide a database that allows users and their radios to be matched on the map for ergonomic use.

8.1.8. Central Time System

The time system shall transmit time signals on a second-by-second basis and in the appropriate format; using the appropriate infrastructure, it shall send these to all systems requiring master clock synchronisation, primarily the systems listed below, and ensure that satellite clocks operate in synchronisation with it.

- Signalling System,
- To the Digital Radio Communication System,
- SCADA System,

- Telephone System,
- CCTV System,
- Public Address System,
- Transmission System,
- Access Control System,
- Passenger Information System,
- Toll Collection System,
- Train-borne Communication Interfaces (where applicable),
- Fire Detection and Alarm System,
- UPS units and protection relays in the MV and DC systems,

time information shall be transmitted.

The system comprises two external GNSS antennas, two fully electronic, synchronised quartz rack-type master clock units and a selector unit, or a fully redundant modular configuration comprising one quartz rack-type master clock unit, sub-master clock units located at each station, a sufficient number of line modules, digital slave clocks, and, if requested by the Authority, analogue slave clocks in accordance with the project and specified location.

The system shall convert the time signals received from the GNSS antenna into the NTP (Network Time Protocol) protocol via the master clock unit located in the central communications room (or, if there is a separate communications room in the depot, in the TCC main equipment room) and transmit them to the transmission system via TCP/IP. All other systems shall synchronise using the master clock unit's IP address via the transmission system. NTP servers shall be redundant.

One single-faced LED display digital clock shall be installed in the Traffic Control Centre (TCC), Station Control Rooms (SOR) and Depot Control Rooms (DOR). Character heights shall be a minimum of 200 mm for the clock in the Traffic Control Centre (TCC), and a minimum of 100 mm in the SOR and DOR rooms.

Time information on the digital clocks shall be displayed in 24-hour format and in the 'hour:minute:second' format.

Time displays on passenger information screens in station concourses and on platforms shall be either analogue or digital.

In the workshop areas of the Depot and Maintenance Yard, one single-faced LED clock with 200 mm character height shall be installed at each end of the workshop to display the time.

The clock system shall include an NTP (Network Time Protocol) server to transmit time data over the network to systems requiring time synchronisation.

The Master Clocks shall be powered by an uninterruptible power supply (UPS) dedicated to the Communication and Control Systems.

System cables will be Cat6 S/FTP LSZH.

Table 8.10 : Distribution of Clock System Equipment by Location

Area	Control Panel / Cabinet	Analogue Clock *	Digital Clock	GPS Antenna
Traffic Control Centre (TCC)			X	X
Station Control Rooms (SOR, DOR)			X	
Communications Room	X			
General Area		X		
Platform		X		
Turnstile Area		X		

* In passenger areas at stations, for the display of time information, depending on the Authority's preference, secondary analogue clocks may not be installed, and passenger information screens may be used instead; alternatively, separate secondary analogue clocks may be installed in addition to passenger information screens. If installed, secondary analogue clocks shall be positioned as specified below, in accordance with station layout and interference plans:

- At each station: on platforms not exceeding 90 metres in length, there shall be at least 1 double-sided secondary analogue clock per platform; on platforms exceeding 90 metres in length, there shall be at least 2 double-sided secondary analogue clocks.
- At each station, there shall be one single-faced secondary analogue clock for each turnstile group.
- For station entrance/exit structures and connecting corridors where the distance to the turnstiles on the ticket hall level exceeds 45 metres, there shall be one single-faced secondary analogue clock.

- At terminal stations, there shall be one single-faced auxiliary analogue clock at platform level for each staircase leading down to the platform from the concourse or intermediate levels.

Under normal lighting conditions at stations, all information displayed on the secondary analogue clocks shall be easily legible from a distance of between 5 metres and 45 metres on both sides.

8.1.9. Access Control System

8.1.9.1. General

An Access Control System shall be designed to control and monitor access to key areas throughout the metro.

The system shall record entry and exit data from card-reader-equipped doors, open/closed status information, and open/closed status information from doors with open-door detection contacts, along with date and time details, into a database, enabling real-time monitoring of the data.

The card-based access infrastructure within the access control system shall also be used as a Staff Attendance Control System (PDKS) to record staff entry and exit times at the station.

The Access Control System shall consist of, but is not limited to, controller units, card readers, magnetic or electric locks, release buttons, emergency exit buttons, magnetic contacts located only on monitored doors, and servers and workstations.

Workstations shall be located in the Station Control Room (SOR) and the Depot Control Room (DOR) to facilitate monitoring and control of the system. Information from the workstations shall be transmitted to the workstation at the Traffic Control Centre (TCC) via the Transmission System. Monitoring and control shall also be carried out from the workstation at the Traffic Control Centre (TCC). The workstation at the Traffic Control Centre (TCC) shall have the authority to intervene with doors at all locations. Workstations at other locations shall only be responsible for monitoring and controlling their respective areas.

Maintenance and card registration operations will be carried out via the TCC workstation. Any card read from any location within the system can be identified and registered in the system. Furthermore, a card reader capable of direct connection to a computer, complete with the necessary software, licence and hardware, shall be allocated to the operator.

Authorisation shall be implemented within the Access Control System software. Operations such as card registration, maintenance and database backups shall only be performed via the central workstation.

In the event of errors occurring at workstations (such as database issues or communication failures in the intermediate transmission system), the system shall be able to operate locally without any problems.

Magnetic contacts shall be installed on both leaves of the controlled double-leaf doors to determine whether both leaves are open or closed.

The Access Control System Workstation shall feature a 2D graphical interface enabling the display of the system architecture, the monitoring and management of door alarms, the control of all controlled doors, and the ability to release doors connected to the security system with a single button press in an emergency. The system shall provide automatic and real-time data flow without the need for manual intervention.

The system shall be capable of operating both centrally and locally.

Doors connected to the Access Control System located in generator buildings, transformer rooms and similar locations separate from the station and depot area shall be monitored and controlled by the Station Control Room or Depot Control Room of the station closest to these facilities.

Table 8.11 : Distribution of Access Control System Equipment by Area

Area Name	**System Panel / Cabinet**	**Card Reader**	**Magnetic Door Contact**	**Magnetic or Electric Door Lock**	**Exit Button**	**Emergency Exit Button**
Traffic Control Centre (TCC)		**X**	**X**	**X**	**X**	**X**
Control Room		**X**	**X**	**X**	**X**	**X**
Depot Control Room		**X**	**X**	**X**	**X**	**X**
Communications Room	**X**	**X**	**X**	**X**	**X**	**X**
Signalling Room		**X**	**X**	**X**	**X**	**X**
Technical Area Corridor		**X**	**X**	**X**	**X**	**X**

Area Name	System Panel / Cabinet	Card Reader	Magnetic Door Contact	Magnetic or Electric Door Lock	Exit Button	Emergency Exit Button
MV/LV/Traction Power Equipment Room		X	X	X	X	X
Platform End Door		X	X	X	X	X
Generator Room		X	X	X	X	X
Spare Parts Storage Rooms		X	X	X	X	X
Battery Room			X			
Ventilation Rooms			X			
Electrical Panel Rooms			X			
Escalator Control Room (if applicable)			X			
Medical Room			X			
GSM Room, Fibre Optic Room			X			
Drainage Pump Room			X			
Fire Pump Room			X			
Standby Room			X			
Cleaning Room			X			
DC Isolation Room			X			
Ventilation Shaft Door			X			

Area Name	System Panel / Cabinet	Card Reader	Magnetic Door Contact	Magnetic or Electric Door Lock	Exit Button	Emergency Exit Button
Emergency Access/Egress Staircase Door/Hatch			X			
Security Lobby Entrance			X			
PSDS Panel Room			X			

Where an electric lock with a magnetic contact is used, no additional magnetic contact shall be designed.

8.1.9.2. Standards

TS EN 50131-1, Alarm systems – Protection against unauthorised entry – Part 1: General requirements

TS EN 50131-2-6, Alarm systems – Intrusion and panic alarm systems – Part 2-6: Opening contacts (magnetic)

TS EN 50131-3, Alarm systems – Intrusion and panic alarm systems – Part 3: Control and notification equipment

TS EN 50131-6, Alarm systems – Intrusion and panic alarm systems – Part 6: Power supplies

TS EN 60839-11-1, Alarm and electronic security systems – Part 11-1: Electronic access control systems – System and component characteristics

TS EN 60839-11-2, Alarm and electronic security systems – Part 11-2: Electronic access control systems – Application guide

8.1.9.3. Card Reader Doors

The entrances to the following security-sensitive areas within the railway line (including the Railway Administration Building) shall be fitted with card readers. Locations where card readers shall be installed:

- Traffic Control Centre (TCC),

- Central Communications Room (or, if there is a separate Depot Communications Room in the depot, the TCC Main Equipment Room and Depot Communications Room),
- Station Control Room (SOR),
- Communications Room,
- Signalling Room,
- Central Signalling Room,
- PSDS Panel Room,
- Power Supply Rooms (Rooms containing HV, LV and DC panels),
- Platform-end tunnel access doors,
- Generator Room,
- Battery Room,
- Spare parts stores,
- Technical corridor entrances

At card-operated doors, the door lock shall be released when a card defined and authorised within the system is swiped.

Doors with card access shall be fitted with door-opening (request) buttons to exit from the inside. It shall not be possible to exit the room using the door handle without first making a door-opening request. Door lock and handle designs shall be selected to suit this configuration.

In the event of an emergency, all locked doors shall be released. To counteract a potential communication failure, emergency buttons capable of cutting the power to the door lock shall be provided alongside the door release (request) buttons.

For special doors of the emergency exit type (doors with panic bars), panic bar contact-type locks shall be selected, and the release function shall be activated by pressing the panic bar. Consequently, no additional exit or emergency exit buttons shall be installed on doors equipped with panic bars.

8.1.9.4. Doors with Open Door Detection Contacts

Open door detection contacts (magnetic contacts) shall be installed on all doors leading to corridors, rooms and similar areas in all buildings within the railway line.

Open door detection shall not be implemented in areas that do not require monitoring or security, such as offices, workshops, rest rooms, WCs, tea rooms, prayer rooms and changing rooms.

Open-door detection contacts (switches) shall be installed on the doors of all other technical rooms within stations, all emergency exit doors and hatches in stations and tunnels, platform-level hatches within passenger areas, all doors of structures outside the station but forming part of the railway system, and roller shutters at station entrances.

8.1.9.5. Controller Unit

A smart controller unit belonging to the system shall be located within the cabinet in the communications room. The monitoring and management of all equipment at the relevant location shall be carried out locally via this unit.

These smart devices shall have a local database capable of storing user authorisations and configurations. The controller shall be able to operate offline independently of the network in the event of any communication failure.

The controller unit shall communicate via an IP Ethernet interface through the transmission system with the main server device located at the TCC and with local/remote monitoring centres. Through this communication, alarm events and access control operations stored on the local controller devices shall be transmitted to the main server, enabling operations such as unlocking a specific door or modifying access permissions.

In addition to storing identity information, access groups and time zones, all controllers shall retain all events in their memory even if the system is offline. Once communication with the main server is re-established, access and alarm events shall be sent to the centre with a date and time stamp.

8.1.9.6. Power Supplies

Controller devices shall have their own power supplies. If they do not have their own power supply, a power supply compliant with the manufacturer’s recommendations shall be installed.

The power supply capacity shall be determined by calculating the energy requirements of all equipment in the system.

In the event of a mains power failure, the entire system, including door locks, shall continue to operate via the UPS line allocated for the Control and Communication systems.

8.1.9.7. Door Lock Mechanisms

Lock mechanisms may be mounted on the door (latch) or on the frame (bolt). The final decision shall be made by the Authority during the design phase, depending on the door models.

Electric locks shall have a minimum holding force of 272 kg (600 lbs).

The operating voltage shall be 12 VDC.

It shall be fail-safe.

They shall be traceable, compatible with wooden, fire-rated, glass and metal doors and the Access Control System, and shall be supplied together with the door strike.

Magnetic locks shall have a minimum holding capacity of 250 kg, an operating voltage of 12–24 V DC, and an LED indicator; they shall be suitable for wooden, fire-rated, glass and metal door types.

For electrically locked doors, whether the locks are fail-safe or fail-secure shall be determined by the Authority.

Relevant standards and regulations shall be taken into account when determining the locking mechanism and operating conditions of fire doors.

The wiring for door lock mechanisms shall be designed to be concealed within the plasterwork.

8.1.9.8. Open Door Detection Contacts

Door open detection contacts shall be of a magnetic design and shall be either flush-mounted or surface-mounted within the door frame.

The wiring for open door sensors shall be designed to be concealed within the plasterwork.

Open door detection contacts shall have a minimum holding capacity of 250 kg.

8.1.9.9. Card Readers

Card readers shall be selected to be capable of reading the ID cards used by staff on existing routes and shall facilitate staff access within their authorised limits.

Card readers shall transmit their data in real-time to the controller device at their location.

Even if the connection between a controller device at a location and the central system is lost, the relevant card readers shall continue to function normally based on the most recent available data.

Card readers shall have a minimum IP54 protection rating.

They shall be capable of operating at ambient temperatures ranging from a minimum of -25 °C to a maximum of +60 °C and at humidity levels ranging from a minimum of 0% to a maximum of 95%.

They shall support all 13.56 MHz cards/tags.

The operating voltage shall be 12 V DC at 50/60 Hz.

The connection type shall be compatible with the Wiegand or OSDP communication standard.

The total connection distance to the control unit shall be a maximum of 130 metres.

8.1.9.10. Output Button

It shall operate on the dry contact principle.

It shall have a single or double contact output.

It shall have an aluminium housing, be suitable for surface mounting, and be of the contact type.

8.1.9.11. Contactless Output Button

It shall have distance and time adjustment functions.

It shall operate at 12 V DC and feature NO/NC/COM relay outputs.

It shall be of the illuminated warning type and suitable for surface mounting.

8.1.9.12. Emergency Exit Button

It shall be double-contact, resettable, suitable for surface mounting and green in colour.

8.1.9.13. Power Unit, 12/24 V

The 12/24 V DC power units shall be short-circuit protected and shall be used for the management of control panels and locks.

8.1.9.14. Contactless ID Cards

Contactless ID cards shall be supplied in the appropriate type for the card readers to be used in the system, with optional encryption, operating at 13.56 MHz, in bank card size, and in the quantity specified in the project.

8.1.9.15. Interface and Integration

An interface shall be designed between the Access Control System and the SCADA System; the open/closed/alarm statuses of the doors shall be transmitted to the SCADA system, and the doors shall be released via the SCADA system.

An interface with the SCADA system shall also be provided for emergency scenarios.

An interface shall be established between the Access Control System and the time-recording system.

Should an alarm be triggered by the Access Control System due to a door being forced open or an unauthorised entry attempt, camera footage from the relevant area where the alarm was triggered, or the nearest area, shall be automatically displayed to the operator.

8.1.9.16. Software and Licensing

All event logs generated by the system shall be retained in event log files for a minimum of 3 months, along with date and time information.

The software to be used shall allow the creation of users with different levels of authorisation. All configurations shall only be carried out by authorised users.

The software shall include a feature for creating and viewing graphical maps.

The graphical map shall be designed to clearly show all areas where the access control system is located, such as platforms, concourse levels, and entrances/exits, alongside a general map showing the entire station/centre.

Maps shall be created using 2D graphics rendered with perspective using appropriate software.

The equipment codes, locations and status information (active, faulty, etc.) of all doors and associated equipment shall be displayed and controlled in real time.

Functional features such as the individual, zone-based or total unlocking and locking of card-operated doors shall be possible.

Information such as the date, time, location, zone, surname, first name, registered ID number, door address and authorisation details entered into the software shall be displayed in real time on the monitoring computer.

Situations such as unauthorised card swiping and forced entry shall be detected via the alarm screen. If the Smart Reader is used, it shall be able to detect cloned cards.

In the event of a fault in any of the system’s equipment (controllers, card readers, supervised inputs for tamper and cable faults, communication faults, etc.), a visual and/or audible warning shall be issued on both the local and central operator screens.

All interface designs shall be submitted to the Authority for approval.

The workstation located in the TCC shall have the authority to intervene with doors at all locations. Workstations at other locations shall be authorised solely to monitor and control the relevant area.

8.1.10. Supervisory Control and Data Acquisition System (SCADA)

8.1.10.1. General

The SCADA System shall be designed to enable the remote monitoring and control of all electrical, electronic and mechanical systems.

The SCADA System shall transmit alarm signals to the Traffic Control Centre (TCC), ensuring the operation of various alarm detection devices and the control of relevant units.

SCADA Sub-systems shall consist of a remote control, data collection and information management system running on a separate server (the server will have hot standby). The SCADA System shall provide remote monitoring and control of power supply sub-systems, as well as remote monitoring and control of all electromechanical sub-systems and the environmental control system.

The SCADA System shall consist of two subsystems. These subsystems are:

- SCADA Power Supply Sub-system (PCS),
- SCADA Environmental Control Subsystem (ECS).

The SCADA Power Supply Subsystem shall monitor the OG System at railway line power supply centres, generator centres, stations, depot and maintenance sites and all other structures within the railway (emergency access/ergess structures, etc.);

- the OG System,
- the DC System,
- the LV System (LV Main Distribution Boards, Power UPS Main Distribution Boards, UPS units),
- 110V DC Battery Chargers and Batteries,
- Emergency Service Generator System,
- The Leakage Current Monitoring and Corrosion Control System,
- Energy Quality and Management System
- Rail-to-Ground Voltage Limiting Devices

shall provide remote monitoring and control functions.

The SCADA Environmental Control Subsystem; at railway line power supply centres, generator centres, stations, depot-maintenance areas and all other structures within the rail system (emergency access/egress structures, etc.);

- Platform Screen Door System (PSDS),
- Axial-Type Tunnel and Station Exhaust Fans,
- Station Ventilation and Exhaust Fans,
- Air Conditioning Units,
- Motorised dampers (electric, pneumatic),
- Compressor Units,
- Motorised Fire Dampers,
- Fire dampers with safety devices,
- Temperature and Carbon Monoxide Sensors,
- Duct-type electric heaters,
- Fire Curtains/Doors,
- Air Compressors,
- Boilers and Radiant Heaters,
- Automatic Car Wash Equipment,
- Station Entry/Exit Shutters,
- Emergency exit hatches,
- Emergency Scenarios,
- Lighting Systems,
- Escalators and Moving Walkways,
- Lifts,
- Gas Fire Suppression System,
- Fire Protection System,
- Motor Control Panels and Ventilation Control Panels,
- Low-Voltage Distribution Panels,
- Drainage and Wastewater System Pumps and Pressure Boosters,
- Communication and Control Systems, including;
    - The Toll Collection System,
    - CCTV System,
    - Public Address System,
    - The Transmission System,

- Passenger Information System,
- Digital Radio Communication System,
- Telephone System,
- Clock System,
- Access Control System,
- Train-borne Communication Interfaces (where applicable),
- Fire Detection and Alarm System

remote monitoring and/or control functions.

8.1.10.2. Standards

The SCADA system shall be designed to comply with the following standards and protocols.

- IEC 61850
- IEC 60870-5-104
- IEC 61131-3 Programming Standard
- TS IEC 62443-4-1 Safety standard for industrial automation products
- IEC 60617 – Standard for graphical symbols for diagrams
- Modbus TCP

8.1.10.3. System Design

The SCADA system shall consist of three levels containing monitoring and control functions.

- Level 0: shall consist of field equipment.
- Level-1: This shall include RTUs/PLCs, local control panels (LCPs), local servers to be installed in the station communication room, and workstations and printers in the station control room.
- Level 2: The hot-standby SCADA central servers to be installed in the central communications room adjacent to the Traffic Control Centre (TCC) (or, if there is a separate storage communications room in the TCC main equipment room, within that room) shall include the archive server/capability, the workstations in the Traffic Control Centre (TCC), the video walls and the printers. It is not mandatory to provide a physically separate server for archiving.

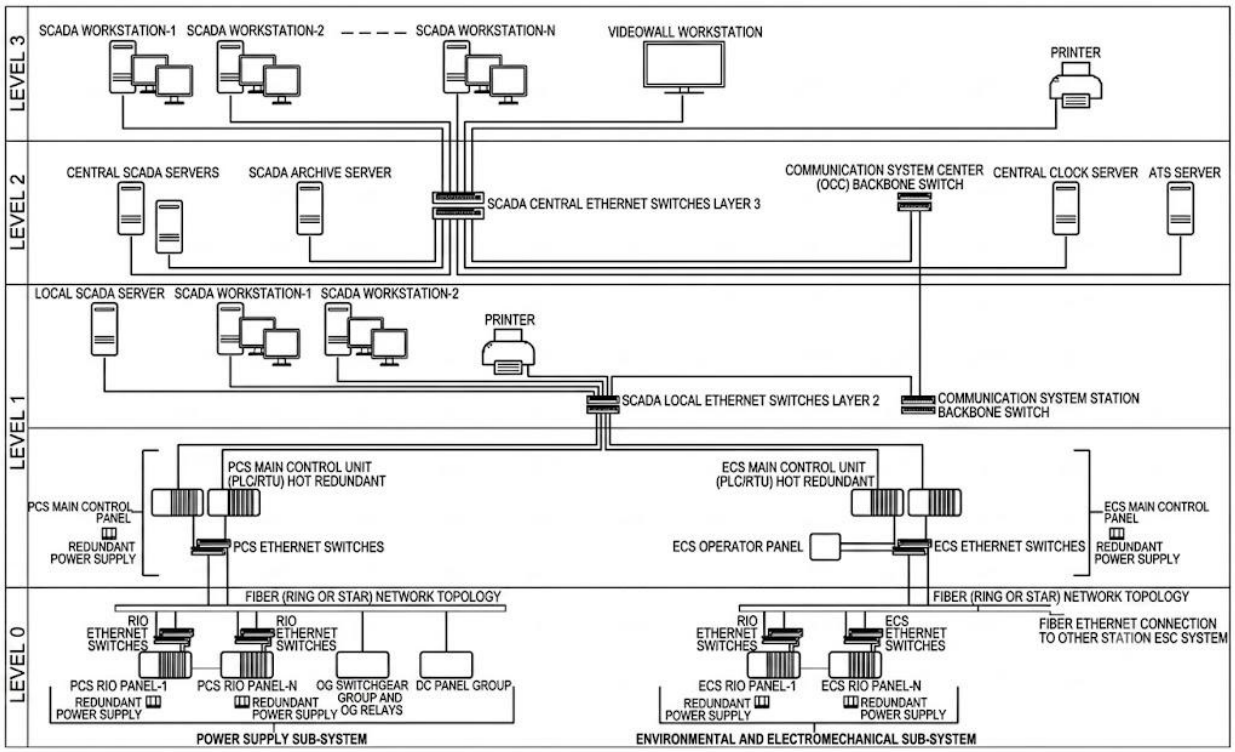


Figure 8.3 : SCADA System Schematic Diagram

The SCADA System shall be capable of performing all monitoring and control functions via workstations at Levels 1 and 2, and shall also be capable of managing smoke extraction scenarios via a local control panel.

In the event of a fault occurring at Level 2 or in the transmission system, the SCADA System shall be able to continue to provide all its functions to the stations and the depot and maintenance area via the local server located at Level 1.

Should the local servers at Level 1 be lost for any reason, smoke extraction scenarios shall be operated automatically or manually via local control panels (LCPs). These local control panels shall consist of a graphic-display touchscreen LCD panel mounted on a suitably protected panel cover in the tunnel ventilation fan rooms. This LCD panel shall feature a graphical interface tailored to the station architecture, with graphical representations similar to those found on the ventilation system pages within the ECS. It shall adhere to the system's common visual design language, ensuring that all objects and icons used throughout the facility represent the relevant unit and form a cohesive whole with the entire project.

The SCADA ECS subsystem shall be designed with a distributed server architecture, whilst the SCADA PCS subsystem shall be designed with a centralised server architecture.

Connections between PLCs/RTUs, servers and workstations shall be designed to be redundant in all cases.

The SCADA Power Supply Subsystem and the SCADA Environmental Control Subsystem shall each have separate (stand-alone), hot-standby RTUs/PLCs to perform the monitoring and control functions within their respective scopes. These hot-standby systems;

- be programmable in accordance with the IEC 61131 programming standard. These programming languages shall fully support industry-standard languages such as ST, LD, FBD, SFC and CFC, which are universally understood.
- The programming infrastructure for all systems shall incorporate a standardised programming structure. The programming structure running the same business unit in one area of the facility and the programming structure running the same task in a different area of the facility will be part of a common programming system. There shall be consistency in the naming of objects/tags and signals.
- The system shall have at least 1 GB of programmable memory and will be capable of executing the entire programme within a sufficiently short time to ensure system performance and stability. Any number of remote input/output units may be added via the main programme. An additional 20% of the total system's input/output capacity shall be reserved as a buffer to accommodate any additional functional requirements.
- The I/O cards to be used shall be designed to allow for replacement whilst the system is powered on. In the event of a fault, only the faulty I/O card can be easily replaced without interfering with the connected or adjacent I/O connection equipment. The replacement shall be carried out without affecting system operation.
- In terms of compatibility with IoT systems, they shall be selected to support MQTT or OPC UA communication protocols.
- The selected analogue input/output modules shall be configurable individually. The communication interfaces and processor shall be integrated within the same module.

The SCADA System shall facilitate data communication between independent PLC/RTU units belonging to two subsystems, between PLC/RTU units and field units, between PLC/RTU units and the SCADA centre, and between PLC/RTU units and the ECS. In cases where generator centres are installed in sections independent of the stations, a common hot-standby PLC/RTU may be used for the SCADA Power Supply and SCADA Environmental Control Subsystems of the generator buildings. This redundant structure will incorporate the features specified above.

Data obtained via PLCs/RTUs shall be aggregated by real-time servers at the Traffic Control Centre (TCC) and retained in the PLC/RTU's memory within the scope supported by the protocol. The real-time servers shall act as a communication controller, managing communication with all remote PLCs/RTUs. PLCs/RTUs and all major online equipment shall be equipped with hot-standby equipment that shall take over without any loss of data in the event of a fault in a piece of equipment.

Data communication between the PLC/RTU and field equipment (between Level 0 and Level 1) shall be provided via two methods. The first is through voltage-free contact circuits within the equipment, and the second is via a communication channel (IEC 61850 or Modbus TCP). In both cases of data provision, the SCADA System shall alert the operator to any adverse conditions that may arise in the field—such as cable breaks, card failures, or contact relay faults—to the extent supported by the field equipment. For this purpose, normally closed (NC) contacts shall be used. The necessary isolation measures shall be taken to ensure that the system and interfaces are not affected by electromagnetic interference in the field. Where data communication between Level 0 and Level 1 is provided via a communication channel, the selected protocol shall be a communication protocol that transmits data with a time stamp. The signal cables here shall be routed separately from power cables to prevent interference, using cable cross-sections compliant with the manufacturer's signal transmission standards and shall be shielded. Products within the system capable of emitting high levels of electromagnetic noise (such as drives) shall be fitted with filters.

Communication between SCADA and MV/DC equipment shall be carried out using the IEC 61850 protocol, and the physical topology shall be a fibre ring structure.

All critical information regarding electromechanical systems—such as equipment failure, downtime, loss of power, or operation under critical conditions— shall be monitored by SCADA as alarm data. Control circuits providing alarm, fault and status information, as well as control functions for electromechanical equipment, shall be designed in accordance with these criteria.

Communication faults occurring in the redundancy system, loss of the backup line, switch or network faults, etc., shall be reported to the SCADA system.

Where data transfer between PLCs/RTUs and field equipment is provided via TCP/IP protocol communication, a redundant communication path (ring or dual-line) shall be established to ensure that a fault at a single point does not affect communication with the equipment.

The communication path for each system (MV, HV, LV, Escalator, etc.) shall be independent and redundant (for example, all escalators at a station shall be grouped together for communication). Where there are multiple MV, LV, etc. system centres in different areas of a station, independent redundant communication paths shall be established. For example, if there are two MV systems in two different areas, the communication paths established for each shall be different.

The communication path shall be designed with redundancy. Furthermore, electromagnetic interference shall be taken into account in the design of data communication between the PLC/RTU and field equipment, and all necessary measures will be taken to prevent unwanted noise.

To create a simpler and more reliable system, a distributed I/O (input/output) architecture shall also be utilised. This shall help to reduce cable lengths.

All cables from the field equipment shall first be terminated in a separate termination panel (RIO: Remote Input Output) and routed to the PLC/RTU cabinet in this manner. Cables entering the RIO panel shall be organised and terminated in the cable tray in such a way as to avoid any tangling; the cables shall not form a pile within the cable tray. Fault information from the RIO panels, which are used to transmit system status/location data, shall also be transferred to the SCADA system. RIO panels shall be positioned in locations where equipment is concentrated.

A ring configuration shall be established for the RIO panels to be installed in a distributed manner in the field, ensuring system redundancy so that operations continue via the other side in the event of a break in one section of the line.

Communication between the PLC/RTU and the Local Server, and between the Local Server and the ECS workstation (Level 1 internal communication), shall be provided independently of the transmission system. This communication shall be carried out via equipment such as switches (industrial switches) to be supplied within the scope of Level 1.

Communication between the PLC/RTU and the Server (Level 1 – Level 2) shall be provided redundantly via the Transmission System and fibre-optic topology using the IEC 60870-5-104 protocol. Any switches (industrial switches) and similar equipment that may be required due to the selected and used communication protocol shall be supplied and installed within the scope of the SCADA System. The fault and operational status information of this equipment shall be displayed by the SCADA system.

Communication between the central server and central workstations, between the central server and the signalling system, and between the central server and the time system (Level 2 internal communication) shall be provided independently of the Transmission System. This communication shall be carried out via switches (industrial switches) and similar equipment to be supplied within the scope of Level 2. Any switches (industrial switches) and similar equipment that may be required due to the selected and used communication protocol shall be designed within the scope of the SCADA system.

The SCADA System Central Server shall be designed with hot standby redundancy. To this end, two separate servers with equivalent hardware shall be installed. This central server shall be designed to provide services from different control console positions, including the relevant workstations located in the Traffic Control Centre (TCC). Furthermore, the central server shall serve the ECS workstations in each Station Control Room (SOR) and Depot Control Room (DOR), as well as local servers for data synchronisation. All workstations related to the SCADA system shall be capable of serving each SCADA subsystem. Some of these workstations shall be configured to serve the SCADA Power Supply Subsystem, some the SCADA Environmental

Control Subsystems, and some will serve both subsystems (supervisor mode). These configurations shall be implemented via the operator authorisation function; if required, any workstation shall be set up to control two subsystems simultaneously.

The human-machine interface at these workstations shall possess the necessary software features to monitor system summaries, station summaries, detailed station and system-based displays, and alarms. The graphical symbols used in these displays shall be designed in accordance with the IEC 60617 standard for graphical symbols in diagrams. For SCADA system screen displays, alarm and report outputs, and real-time colour screen display outputs, the specified number of laser printers as outlined in the TCC project shall be installed as part of the system.

The specifications for the Video Walls to be installed for the SCADA System are provided under the heading “Traffic Control Centre (TCC) Video Wall System”.

The ECS workstations to be located in the Station Control Rooms (SOR) shall have the same specifications as the Traffic Control Centre (TCC) workstations connected to the central server. Under normal operating conditions, the ECS workstations shall function as service consoles connected to the central server; in the event of a central server failure or a transmission system failure, they shall connect to the local server and operate as workstations connected to the local server. Once the central server failure has been resolved, the local server shall transmit the status and alarm information it has recorded during the failure period to the central server without any data loss.

The ECS workstations located in the station control room shall possess the necessary software features to monitor the station summary, system summary, system-based detailed displays and alarms. These workstations shall be capable of performing all functions of the SCADA system pertaining to the relevant station whilst serving as a command and control console connected to both the central and local servers. Through software-based authorisation, the ECS workstations shall perform the monitoring and control functions of the SCADA Power Supply and SCADA Environmental Control Subsystems. Each workstation in the station control room (SOR) shall be capable of being used as a substitute for another. There shall be one laser printer in each station control room for SCADA system outputs.

The visual interface to be created in the SCADA System’s human-machine interfaces (HMI) shall consist of dedicated pages allocated to each system; at the same time, all system screen views shall be accessible from a main page. Graphic page and object designs shall be tailored to the operational requirements.

The SCADA Environmental Control Subsystem shall perform heating, ventilation and energy-saving functions. The system shall continuously monitor connected data input points and report any unusual developments during control operations.

In developing the operational philosophy of the SCADA Environmental Control Subsystem, evacuation procedures at stations and in tunnels, smoke dispersion, air movement, temperature, control, etc., shall be taken into account.

Within the scope of the SCADA Environmental Control Subsystem, three different control modes shall be implemented at the TCC, the station control room (SOR) and the station ventilation fan room locations:

Manual Mode;

Equipment serving passenger areas and tunnel ventilation equipment shall be operated manually during testing or in the event of an emergency.

Automatic Mode;

Equipment serving passenger areas and tunnel ventilation equipment shall operate automatically in accordance with pre-programmed operating conditions.

Semi-Automatic Mode;

Equipment serving passenger areas and tunnel ventilation equipment shall operate in accordance with pre-programmed operating conditions; however, starting, stopping or resetting (re-initialising) the operation shall be carried out manually.

The SCADA Environmental Control Subsystem shall be able to operate equipment serving passenger areas and tunnel ventilation equipment in the following order of priority;

- Central control from the TCC,
- From the Station Control Room (SOR),
- Operation from fan plant rooms via LCP and MCC panels.

The SCADA System shall manage and monitor emergency scenarios.

The SCADA System shall control the scenario-based behaviour of all electromechanical equipment according to station, tunnel, depot and maintenance area and vehicle emergency scenarios. The SCADA System shall also control Environmental Control System equipment within the scope of emergency scenarios to manage smoke extraction. Some of the SCADA System's functions related to emergency scenarios are as follows:

- Initiating the scenario function of smoke extraction systems,
- Initiating the scenario function of turnstiles,
- Initiating the scenario function of controlled doors,

- Activating the signal lights on evacuation routes,
- Initiating the scenario function for ‘No Entry’ sign lighting,
- Initiating the scenario function for lifts,
- Initiating the scenario function for escalators and moving walkways,
- Initiating the evacuation announcement function,

Depending on the emergency scenarios to be created, all systems actively involved in the scenario shall be controlled by the SCADA System throughout the scenario, and the behaviour of the equipment associated with these systems during the scenario shall be monitored. In addition to the functions described above, the SCADA System shall also ensure that any other functions required by the approved emergency scenarios are carried out.

The scenarios for smoke extraction systems within the scope of emergency scenarios shall be initiated based on position data obtained from the signalling system. In this context, the necessary interfaces between the ECS and signalling systems shall be provided.

The scenario functions of the smoke extraction systems within the scope of emergency scenarios shall be carried out under the control of the SCADA Environmental Control Subsystem, via equipment within the Environmental Control System. The SCADA System shall suggest pre-defined evacuation scenarios to the operator based on regional fire alarm information received from the Fire Detection and Alarm System. Smoke extraction scenarios shall only be initiated with the operator’s approval. The scenarios may also be initiated manually by the operator in the event of a failure of the Fire Detection and Alarm System or a fault in the communication link between the Fire Detection and Alarm System and the SCADA System. Should the fire alarm not be confirmed within a specified timeframe, these scenarios shall be initiated automatically. The decision regarding this timeframe shall be made by the Authority.

Furthermore, in order to ensure that Vehicle Fire Emergency Scenarios are recommended to the operator in accordance with the location, using the fire alarm information received by the SCADA System from the Train-borne Communication Interfaces (where applicable), all necessary information, such as train position and ID details, shall also be obtained from the signalling system.

Some of the ECS’s tasks in smoke extraction scenarios are as follows:

- Initiating the locking process of fire dampers in ventilation systems,
- Initiating the operation of smoke extraction systems,
- Initiating the operation of the fresh air pressurisation system,
- Initiating the fire curtain/door scenario function.

Ageing data for redundant fans, pumps, and other equipment shall be displayed in the ECS software on the relevant equipment.

8.1.10.4. Input/Output (I/O) Lists

The I/O lists to be connected to SCADA are generally specified below.

8.1.10.4.1. SCADA Power Supply Subsystem I/O Lists

The I/Os listed below shall be connected to the SCADA system via the SCADA Power Supply Subsystem PLC/RTU (PCS-PLC/RTU).

It is understood that the term “circuit breaker” in the lists below refers not only to miniature circuit breakers (MCBs) but also to residual current devices (RCDs) and overcurrent-protected residual current devices (MCBOs). (Where MCBs and RCDs are used together in any distribution board, the term “circuit breaker” shall be understood to refer to both MCBs and RCDs. Similarly, where MCBOs are used in place of MCBs and RCDs in any distribution board, the term “circuit breaker” shall be understood to refer to MCBOs.)

MV Switchgear

- Circuit breaker on/off commands
- Circuit breaker open/closed position information
- Circuit breaker alarm reset commands
- Circuit breaker remote/local status information
- Relay internal fault
- Protection relay communication interrupted / blocked information
- Differential protection relay communication interrupted / blocked information
- Circuit breaker carriage position information (service-test-out-intermediate)
- Drawer-type voltage transformer position information (service-test-out)
- Earthing switch open-closed status
- Main busbar energised-de-energised status information
- Cable side energised/de-energised status information
- Voltage transformer circuit breaker status information
- Short-circuit and overcurrent trip information
- Earth fault trip information
- Information on tripping due to undervoltage and overvoltage faults

- Information on tripping caused by faults in 110V DC low-voltage circuits
- Information on whether the circuit breaker socket is fitted or not
- Information on whether the drawer-type voltage transformer socket is fitted or not
- Circuit breaker spring discharged information
- Information on tripped 110V supply circuit breakers and other circuit breakers
- Auxiliary power supply fault information
- Heater on/off status information
- Shutdown authorisation information
- Phase current information
- Phase-to-phase voltage information
- Active, reactive and apparent power information
- Power factor data
- Active and reactive energy data
- Circuit breaker operation count data
- Phase current THD values (Only at local electricity distribution company inputs)
- Phase voltage THD values (Only at local electricity distribution company feeders)
- Information on differential protection, warnings and tripping (Only at ring feed-in and feed-out cells)
- Transformer temperature alarm and trip information (For all transformer cells)
- Trip information from the traction power system (where applicable)
- Traction power system disconnection authorisation information (where applicable)

Unless otherwise specified, the information/commands provided above shall be required for all cell types. Furthermore, fault and warning information with low alarm priority will be grouped and transmitted to the SCADA system as a general alarm signal.

Transformers (Internal Demand, Power Transfer, Cer, Generator)

- Relay internal fault information for the transformer temperature protection relay and (if present) the transformer fan control relay
- Auxiliary power supply fault information
- Earth fault warning and trip information

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Rectifiers

- Rectifier temperature warning and trip information
- Rectifier auxiliary fuse trip information
- Information on rectifier diode fault warnings and resets (to be grouped separately for the RST phases of rectifiers in star and delta configurations)
- Enclosure leakage fault warning and trip information

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Traction Power Return/Feeder Monitoring Panels

- Information on isolator open-closed positions
- Busbar voltage warning and trip information
- Total return current information for each rectifier group
- Relay internal fault
- Protection relay communication interrupted / blocked information
- Information on tripped 110V supply circuit breakers and other circuit breakers
- Enclosure leakage fault warning and tripping information
- Disconnector operating lever engaged

In addition, fault and warning messages with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal

Traction Power Feeder/Switching Equipment

- Circuit breaker open-close commands
- Circuit breaker open-closed position data
- Circuit breaker alarm reset commands
- Circuit breaker trolley position information (service-test-out-intermediate)
- Circuit breaker remote-local status information
- Busbar energised/de-energised status information
- Cable side energised/de-energised status information

- Voltage fault and trip information
- 110V DC low-voltage fault and trip information
- Current fault and trip information
- Enclosure leakage fault warning and trip information
- Current measurement information
- Voltage measurement information
- Power information
- Internal relay fault
- Protection relay communication interrupted / blocked information
- Information on tripped 110V supply circuit breakers and other circuit breakers
- Information on closure permits
- Circuit breaker operation count information
- Cable monitoring alerts and tripping information (Only in line feed cells)
- Line test information (successful, failed, blocked, fuse blown) (Only in line feed cells)
- Neighbouring line feed-in cell intertrip information (Only in line feed-in cells)
- Intertrip commands for neighbouring line feed cells (Only in line feed cells)

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

DC Motorised Disconnectors

- Disconnector open-close commands
- Circuit breaker open-closed position data
- Line (load) side energised-de-energised status information
- Busbar (source) side energised/de-energised status information
- Circuit breaker remote-local status information
- Information on control voltage supply units and other unit tripping events
- Information on body leakage fault warnings and tripping
- Disconnector operating lever engaged

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

DC Manual Disconnectors

- Information on disconnector open-closed positions
- Line (load) side energised-de-energised status information
- Busbar (source) side energised/de-energised status information
- Control voltage supply relay and other relay trip information
- Enclosure leakage fault warning and tripping information

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Rail-to-Earth Voltage Limiting Panels (VLD)

- Device reset commands
- Contactor status information (open-closed-fault-blocked)
- Fault and trip information
- Voltage limiter fault
- Information on the auxiliary control voltage supply unit and other unit tripping events

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Power Quality and Management System

- Input voltage present/absent status and warning information
- Main switch on-off-faulty status and warning information
- Output circuit breaker tripped, automatic switch tripped information (general fault)
- Temperature warning and trip information
- Earth fault warning and trip information
- Control/power analyser information (current, voltage, power factor, active and reactive power, and energy)
- Inductive reactive power, capacitive reactive power, harmonic limit value warning information
- Fan fault
- Control/energy analyser fault
- System on/off information

- System enable/disable commands
- Stage enable/disable commands

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

LV Main Distribution Boards

- Circuit breaker (main feed, coupling, non-essential busbar circuit breakers) open-close commands
- Circuit breaker (main feed, coupling, non-essential busbar circuit breakers) open-closed position informationCircuit breaker (main feed, coupling, non-essential busbar circuit breakers) in service-under test-out of service information
- Circuit breaker (main feed, coupling, non-essential busbar circuit breakers) remote-local status
- Circuit breaker (main input, coupling, non-mandatory busbar circuit breakers) fault information
- Busbar energised-de-energised status information
- Low voltage, overvoltage fault information
- Control voltage low fault information
- Panel heater fault information
- Phase current information
- Phase-to-phase voltage information
- Active, reactive and apparent power information
- Power factor information
- Active and reactive energy data
- 110V supply circuit breaker and other circuit breaker trip information
- Load shedding commands
- Load shedding status information
- Output circuit breaker position and fault information
- Current, voltage, active, reactive and apparent power, active and reactive energy, and power factor data for all load groups will be transmitted to the SCADA system.

In addition, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

110 V DC Battery Chargers and Batteries

- AC main input switch position data
- DC main output switch position data
- AC input voltage data
- DC output voltage data
- Rectifier fault information
- DC voltage low-high warning information
- Chassis leakage faults and tripping information
- Load output circuit breaker(s) tripped information
- Temperature warning information
- Battery power supply status information
- Battery switch position information
- Battery compartment temperature alarm information
- Battery discharge critical level warning and trip alarm information

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Uninterruptible Power Supplies (Power, Control-Communication, Signalling UPSs)

- AC main input switch position information
- AC input-output voltage information
- Rectifier-inverter-reserve static switch fault information
- Manual bypass switch position information
- Output circuit breaker trip information
- Battery supply status information
- Backup AC power supply status information
- Overload warning information
- Battery supply switch and battery group switch position information
- Battery room temperature alarm information
- Battery discharge critical level warning and trip alarm information
- Warning alarm information when the temperature exceeds the specified limit value.

- Information on DC voltage low and high warnings
- Chassis leakage warning and trip information

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Main Power UPS Distribution Panels

- Panel input voltage present/absent status and warning information
- Main switch on/off/faulty status and warning information
- Information on tripped output circuit breakers and tripped automatic switches (general fault)

In addition, error and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Earth Leakage Monitoring and Corrosion Control System

- Leakage current system warning information
- Earth leakage fault information
- Internal fault information

All stations and the control centre shall be transmitted to SCADA separately. Furthermore, fault and warning information with low alarm priority shall be grouped and transmitted to SCADA as a general alarm signal.

Emergency Service Generator System

- Phase current information
- Phase-to-phase voltage data
- Active, reactive and apparent power data
- Power factor data
- Active and reactive energy data
- Generator frequency data
- Fuel level data
- Compressed air tank pressure information
- Generator on-off status information
- Generator operating mode information
- Generator start-up and shutdown commands

- Generator operating mode commands
- Generator voltage, current and earth fault information
- Generator coolant temperature warning information
- Generator speed fault warning information
- Generator oil pressure and temperature warning information

Additionally, fault and warning information with low alarm priority will be grouped and transmitted to the SCADA system as a general alarm signal.

8.1.10.4.2. SCADA I/O Lists

The I/Os listed below shall be connected to the SCADA system via the SCADA Environmental Control Subsystem PLC/RTU (ECS-PLC/RTU).

It is understood that the term “circuit breaker” in the lists below refers not only to miniature circuit breakers (MCBs) but also to residual current devices (RCDs) and overcurrent-protected residual current devices (MCBOs). (Where MCBs and RCDs are used together in any distribution board, the term “circuit breaker” shall be understood to refer to both MCBs and RCDs. Similarly, where MCBOs are used in place of MCBs and RCDs in any distribution board, the term “circuit breaker” shall be understood to refer to MCBOs.)

8.1.10.4.2.1. Mechanical Equipment & Systems

Platform Screen Door System (PSDS)

- Power failure information
- Door status information
- Door open/closed status information
- Door fault information
- Door isolation information
- Door open-close commands (only within fire scenarios)

Additionally, low-priority alarm, fault and warning information shall be grouped and transmitted to the SCADA system as a general alarm signal.

Escalators and Moving Walkways

- Up-down, forward-backward operation and stop information
- Up-down, forward-backward operation and stop commands
- Escalator fault information

- Information on stoppage via the emergency stop button
- Reset commands
- Maintenance and test mode status information
- Escalator distance information
- Input voltage present/absent status and warning information

Escalator fault information covers all faults relating to the escalator. Specific and critical warnings shall be transmitted to the SCADA system independently, whilst other warnings shall be grouped and transmitted as a general alarm signal.

Lifts

- Emergency warning information
- Elevator in-service and out-of-service status and warning information
- Up/down operation and stop commands (to be used in emergency evacuation scenarios)
- Lift position information (floor/level)
- Information on 'Doors blocked' warnings
- Low oil level warning information
- High temperature warning information
- Safety device warning information
- Maintenance and test mode status information
- Input voltage present/absent status and warning information

Additionally, low-priority fault and warning information shall be grouped and transmitted to the SCADA system as a general alarm signal.

Gas Fire Suppression System

- Gas Fire Suppression System: 1st alarm, 2nd alarm, fault and cylinder discharge information (separately for each room)

This information shall be transmitted to the SCADA System via the Fire Detection and Alarm System.

Fire Protection System

- Water tank level information (there will be 4 levels: very low, low, high, very high)
- Fire pump on/off status information

- Fire pump fault information
- Air compressor on/off status information
- Air compressor fault information
- Sprinkler system, fire cabinet and hydrant system valve, flow sensor switches and pressure switch status information (status information for all valves, including XXSKİ connection valves, shall be monitored)
- Preaction valve status information
- Fire pump on/off status

This information shall be transferred to the SCADA system via the Fire Detection and Alarm System.

Motor Control Panels, Ventilation Control Panels

- Panel input voltage present/absent status and warning information
- Main switch on/off/faulty status and alarm information
- Information on tripped output switching elements (general fault)

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Drainage Pumps

- Pump on/off status information
- Pump activation/deactivation commands (for tunnel drainage pumps only)
- Pump manual/automatic status
- Pump fault information
- Power failure information
- Tank (drainage pit) low-high level information (there shall be 4 levels: very low, low, high, very high)

Additionally, low-priority fault and warning information shall be grouped and transmitted to the SCADA system as a general alarm signal.

Wastewater Pumps

- Pump on-off status information
- Pump fault information

- Power failure information
- Tank low/high level information
- Pump manual/automatic status

Additionally, low-priority fault and warning information shall be grouped and transmitted to the SCADA system as a general alarm signal.

Pressure boosters

- Pump fault information
- Power failure information
- Tank low-high level data

In addition, low-priority fault and warning information shall be grouped and transmitted to the SCADA system as a general alarm signal.

Axial-Flow Tunnel and Station Exhaust Fans

- Fan running and stopped information in supply and exhaust directions
- Fan supply-exhaust direction operation and stop commands
- Fan on/off status
- Speed information for tunnel ventilation fans
- Power failure information
- Frequency drive fault information
- Frequency drive instantaneous speed information
- Frequency drive speed setting commands
- Information on fans stopped via the emergency stop button
- Damper position information
- Damper fault information

Additionally, low-priority fault and warning information shall be grouped and transmitted to the SCADA system as a general alarm signal.

Station Ventilation and Exhaust Fans

- Fan operating status information
- Fan start/stop commands

- Fan on/off status information
- Power failure information
- Belt breakage alarm information
- Dirty filter warning information
- Information on fan being stopped via the emergency stop button
- Damper position information
- Damper fault information

In addition, low-priority fault and warning messages shall be grouped and transmitted to the SCADA system as a general alarm signal.

Air Conditioning Units

- Air-conditioning unit on/off status
- Air conditioning units general alarm information

Temperature values for critical rooms (signalling, MV/LV/Traction power equipment rooms, etc.) and office rooms (occupied rooms; prayer room, SOR, offices, etc.) shall be displayed in the section relating to the relevant air-conditioning equipment, including HRV and similar systems. Additionally, low-priority fault and warning information shall be grouped and transmitted to the SCADA system as a general alarm signal.

Electric Motor-Operated Dampers

- Damper position information
- Damper open-close commands

Pneumatic Motorised Dampers

- Damper position data
- Damper open-close commands

Alarms from the compressed air system used for pneumatic dampers shall be transmitted to the SCADA system as general alarms.

Motorised fire dampers

- Damper position information
- Damper open-close commands

Spring-loaded fire dampers

- Damper position information

Temperature Sensors

- Temperature level information (Celsius)
- High and very high temperature warning information

Carbon monoxide sensors

- Carbon monoxide level information (PPM)

Ducted Electric Heaters

- Electric heater on/off status information
- Electric heater on/off commands (for each stage)
- Blower air temperature level information (Celsius)
- Electric heater high-temperature warning information

Additionally, low-priority fault and warning information shall be grouped and transmitted to the SCADA system as a general alarm signal.

Fire Curtains/Doors

- Door open/closed status information
- Door open/close commands
- Door fault information

Air compressors

- Air compressor on/off status information
- Air compressor fault information

Boilers

- Boiler inlet/outlet water temperature information
- Boiler pump on/off status information
- Boiler pump general fault information
- Boiler thermal fault information
- Boiler maintenance switch information

- Boiler command error/rejection information
- Boiler start and stop commands
- Boiler automatic/manual command and information

Radiant Heaters

- Radiant heater fan on/off status information
- Radiant heater fan fault information
- Radiant heater system sensor information
- Radiant heater system operation commands
- Radiant heater system on/off status information
- Radiant heating system command error/rejection information
- Radiant heating system automatic/manual information

Automatic Washing Plant Equipment

- Minor alarm information
- Major alarm information

In the event of major (critical) alarms, an interface shall be established with the signalling system to provide notification that a critical alarm has been received. Should the signalling system receive a critical alarm, it shall not operate automatically and shall notify the ATS operator via both an alarm page displaying “Washing Unit Critical Alarm” and a visual warning on the washing unit icon on the TCC/signalling screen.

8.1.10.4.2.2. Electrical Equipment & Systems

Station Control Room and Communication Room Equipment Power Supply Panels

- Information on panel input voltage presence/absence status and warnings
- Information on main switch status (on/off/faulty) and warnings
- Information on tripped output circuit breakers (general fault)

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Signalling Room Equipment Power Supply Panels

- Panel input voltage present/absent status and warning information
- Information on tripped output circuit breakers (general fault)

- Main switch on/off/faulty status and warning information

Furthermore, error and warning messages with low alarm priority shall be grouped and transmitted to the ECS as a general alarm signal.

Station Lighting and Socket Panels (Normal)

- Main switch on/off/faulty status and warning information
- Main input voltage present/absent status and warning information

Lighting Section:

- Input switch on-off-faulty status and warning information
- Input voltage present/absent status and warning information
- Station passenger area lighting activation and deactivation commands
- Station passenger area lighting on/off information
- Information on tripped output relays for station passenger area lighting (general fault)
- Information on tripped circuit breakers for lighting outside station passenger areas (general fault)

Socket Section:

- Information on input switch status (on, off, faulty) and warnings
- Input voltage present/absent status and warning information
- Information on tripped output circuit breakers (general fault)

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Station Lighting-Socket Panels (Emergency)

- Main switch on-off-faulty status and warning information
- Main input voltage present/absent status and warning information

Lighting Section:

- Input voltage present/absent status and warning information
- Input switch on-off-faulty status and warning information

- Station passenger area emergency lighting activation and deactivation commands
- Station passenger area emergency lighting on/off information
- Information on tripped emergency lighting circuit breakers in station passenger areas (general fault)
- Information on tripped emergency lighting circuit breakers outside station passenger areas (general fault)

Socket Section:

- Information on input switch status (on/off/faulty) and warnings
- Input voltage present/absent status and warning information
- Information on tripped output circuit breakers (general fault)

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Tunnel Normal & Emergency Lighting Panels

- Tunnel lighting “on mains – off mains”, “on UPS – off UPS” information
- Mains main switch on-off-faulty status and warning information
- Information regarding the UPS main switch being on, off, or faulty, and associated warnings
- Tunnel mains lighting activation and deactivation commands
- Tunnel UPS lighting activation and deactivation commands
- Information regarding tripped circuit breakers for tunnel mains lighting (general fault)
- Information on tripped circuit breakers for tunnel UPS lighting circuits (general fault)
- Tunnel mains lighting on/off status
- Tunnel UPS lighting on/off status
- Tunnel mains lighting switched on from the site – switched on from SCADA information
- Tunnel UPS lighting activated from the site – activated from SCADA information

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to SCADA as a general alarm signal.

Tunnel Socket Panels

- Panel input voltage present/absent status and warning information
- Main switch on/off/faulty status and warning information
- Information on tripped output circuit breakers (general fault)

In addition, error and warning messages with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Emergency Control Panels

- Panel input voltage present/absent status and warning information
- Main switch on-off-faulty status and warning information
- Emergency scenario active/inactive status information
- “Danger: Do Not Enter” sign lighting activation/deactivation commands
- Information on tripped output relays (general fault)

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Open-Air Circuit Breaker Heaters Secondary Distribution Panels (if any)

- Panel input voltage present/absent status and warning information
- Main switch on/off/faulty status and warning information
- Information on tripped output circuit breakers (general fault)
- Manual-automatic operating status information

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Open-Air Scissor Heater Field Control Panels (if applicable)

- Panel input voltage present/absent status and warning information
- Main switch on-off-fault status and warning information
- Information on tripped output circuit breakers and earth leakage relays (general fault)
- Information regarding the on/off status and warnings of the switch heaters

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Low-Current Equipment UPS Emergency Power Panels

- Panel input voltage present/absent status and warning information
- Circuit breaker trip information (all circuits will be monitored)

Fare Collection System Equipment UPS Power Supply Panels

- Panel input voltage present/absent status and warning information
- Circuit breaker trip information (all circuits will be monitored)

Mechanical Equipment Power Supply Panels

- Panel input voltage present/absent status and warning information
- Main switch on/off/faulty status and warning information
- Information on tripped output circuit breakers (general fault)

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

Solar Power System (SPS)

- Inverter DC input current, voltage and instantaneous power information,
- Inverter output current, voltage, instantaneous power and frequency information,
- Information on the total power supplied to the grid,
- Efficiency data,
- Energy production data for the current day, the last month, the last year and since installation,
- Fault information (faults occurring on panels, inverters, etc.)

Additionally, fault and warning information with low alarm priority shall be grouped and transmitted to the SCADA system as a general alarm signal.

8.1.10.4.2.3. Signalling, Communication and Control Systems & Equipment

Signalling Panels

- Information on panel input voltage presence/absence status and warnings
- Circuit breaker trip information (all lines shall be monitored)

Platform Emergency Stop System

- Platform Emergency Stop button active/inactive status information

Clock System

- Clock system general alarm information

Signalling System

- Transmission System minor alarm information
- Transmission System major alarm information

Digital Radio Communication System

- Digital Radio Communication System minor alarm information
- Digital Radio Communication System major alarm information
- Power on/off status

Public Address System

- Public Address System general alarm information
- Emergency announcement commands

CCTV System

- CCTV system general alarm information

Access Control System

- Access Control System general alarm information
- Release commands for controlled gates

Fare Collection System

- Turnstile position information
- Turnstile operating position commands
- Turnstile power on/off information
- Turnstile in-service/out-of-service information
- Turnstile communication error information
- Turnstile release commands
- Turnstile locking commands
- Turnstile normally open (NO) or normally closed (NC) operating commands and

information

Passenger Information System

- Passenger Information System general alarm information

Telephone System

- Telephone System general alarm information

Train-borne Communication Interfaces (where applicable)

- Onboard CCS system general alarm information

Fire Detection and Alarm System

- Zone fire alarm information
- General fault warning information for alarm panels; Equipment isolation information
- Information on 'Fire alarm not received' signals
- Fire protection system
- Control data (The data to be transmitted to the ECS Control System is described in the Fire Protection System Information section.)
- Gas Extinguishing System
- Control data (The data to be transmitted to the ECS Control System is described in the Gas Extinguishing System Data section.)

In addition, low-priority alarm, fault and warning information shall be grouped and transmitted to the SCADA System as a general alarm signal.

Major and minor alarms from the systems listed above (Clock, Transmission, Radio, Public Address, CCTV, Access Control, Fare Collection, Passenger Information, Telephone, Fire Detection and Alarm Systems) shall be transmitted to the SCADA System via a suitable communication protocol (Modbus-TCP/IP, Ethernet, SNMP, etc.).

Furthermore, low-priority fault and warning information shall be grouped and transmitted to the SCADA System as a general alarm signal.

For the INRAIL driver-operated ETCS Level 1 line, fault information from tunnel/covered-section dynamic signage, if provided, shall be transmitted to the SCADA system.

General, major and minor alarm information identifies any internal fault condition in the equipment of the relevant system. All systems shall be designed to provide the specified alarm signals. All stations and the centre shall be transmitted to the SCADA system separately.

8.1.10.5. Interface with Other Systems

The SCADA System's hot-standby servers shall obtain time information from the central time system and share it with all online equipment. The time of occurrence for each alarm shall be linked to the alarm at the lowest level (time stamp). In this way, each alarm shall contain the actual time of occurrence.

The SCADA system shall have an interface with the Signalling system. The SCADA system shall provide the Signalling system with information on the energised or de-energised status of the catenary (conventional catenary if applicable) or third rail, and shall receive information from the Signalling system regarding train stalling incidents, train location data and critical alarms.

In addition to the interfaces mentioned above, the SCADA system's other interfaces with the Train-borne Communication Interfaces (where applicable), Fire Detection and Alarm System, and Environmental Control System are detailed under the heading "8.1.11.2 System Design ".

The necessary licences and features to enable two-way OPC UA communication with the systems shall be available on the SCADA Server.

8.1.10.6. Software and Licensing

Alarms, event logs and analogue data from the SCADA System shall be stored on the archive server for a minimum of 3 months.

Via maintenance laptops, which shall be provided as part of the SCADA System and pre-loaded with all necessary software licences, it shall be possible to configure the server, workstation and PLC/RTU software. All documents and projects relating to the SCADA System, as well as digital versions of the maintenance manuals, shall be available on this laptop.

The SCADA system shall have a 20% redundant capacity in terms of both software and hardware. To ensure this redundancy, spare modules, cards and other equipment shall be incorporated into the design for each cabinet, panel and relevant system components.

8.1.11. Passenger Information System

8.1.11.1. General

The Passenger Information System shall provide passengers with information regarding the destination of the first and second trains departing from the platform, the number of minutes remaining until their departure, and directional information regarding which platform the train shall

depart from at terminal stations. Additionally, the number of carriages comprising the next train and the subsequent train (e.g., 4-car set, 8-car set, etc.) shall be displayed on the screens.

The system shall be live, reflecting all changes—such as the arrival time of the next train, information messages and safety information—in real time. The arrival time for the next train shall be displayed in minutes.

To ensure that updated train information can be automatically relayed to visually impaired passengers within a 5-metre radius at floor level from beneath the passenger information screens, the screens shall also be equipped with the necessary software and hardware for audio output and voice announcements.

All variable displays, such as information and scrolling text on the screens, shall be displayed smoothly and without flickering. To this end, screen refresh rates shall be at a level imperceptible to the human eye.

The system design shall comply with TS EN 55024, TS EN 55032 and other relevant TSE and EN standards.

8.1.11.2. System Design

Real-time data transmission to the screens located at all stations shall be facilitated via the Passenger Information System workstation situated at the TCC.

The Passenger Information System server shall be located in the central communications room (or, if there is a separate communications room in the depot, in the TCC main equipment room). All passenger information screens located along the line shall be connected to this server via the transmission system.

The system design shall include the following:

- All equipment and installations necessary to ensure that train movement information is provided effectively to all passenger stations,
- The provision of a message transmission system between stations,
- Connection to the transmission system,
- The necessary inputs from the Central Timing System,
- The interface with the signalling system.

The signalling system shall transmit to the Passenger Information System information regarding the exact positions and configurations (number of carriages) of all trains in operation within the system, compared against train identification numbers, and directional information regarding

which platform the train shall depart from at terminal stations, under both scheduled and unscheduled operating conditions.

This information shall be interpreted in real time, using the central time system (hour:minute basis) as a reference, to transmit line-specific details regarding the expected departure times of the first and second trains from each station platform to each station; and to transmit directional information regarding which platform the train will depart from at terminal stations in cases of double-track operations. Train destinations shall also be included in this information. Information regarding out-of-service trains and the last service shall also be displayed on the screens.

The system shall obtain real-time information from the signalling system regarding vehicle entry, vehicle departure, the vehicle's location, time and vehicle number.

In addition to normal operational information, or in the event of operational disruptions, the system shall be capable of displaying a message selected by the operator from a pre-prepared set of messages, or any manually prepared message, on the screens.

8.1.11.3. Passenger Information System Equipment Layout

The equipment to be installed at stations shall consist of the following elements, without being limited to them:

- Passenger Information Screens
- Data transmission cables within the station area, including supports and fixings
- Equipment required for connection to the data transmission system or fibre optic cable
- Cables and connections for 230V power supply.

The locations and types of screens will depend on the station layout and interference plans, but will generally comply with the following conditions:

- At each station, there shall be a number of double-sided screens per platform, as specified in the design, depending on the platform length (the distance between adjacent screens will not exceed 45 metres),
- At each station, there shall be one single-sided screen for each turnstile entrance area,
- One single-sided screen shall be installed for station entrance/exit structures and connecting corridors where the distance to the turnstiles on the ticket hall level exceeds 50 metres,
- At terminal stations, there shall be one single-sided screen at platform level for each staircase area serving passengers descending to the platform from the concourse or intermediate levels.

Power supply for all information screens shall be provided via the UPS line allocated to the control and communication systems.

8.1.11.4. Information Display Specifications

Information screens shall display text in legible Turkish characters for both displayed information and static information. An integrated clock shall be located in a section of the screen with sufficient space allocated for it.

Passenger information screens shall be of an industrial type.

Screens for indoor use shall have a minimum IP 54 protection rating, whilst those for outdoor use shall have a minimum IP65 protection rating.

They shall be fitted with at least 6 mm thick tempered, non-reflective glass.

Depending on the location, they shall be single- or double-sided, LED-lit, and mounted at a height of between 2.20 m and 2.50 m above the platform. Under normal lighting conditions at stations, all information displayed on the screen (including the integrated clock) shall be easily readable from a distance of between 5 metres and 45 metres on both sides.

Ambient brightness shall be detected by a sensor on the device, and the display brightness shall be adjusted automatically.

The lifespan of the LEDs to be used in the displays shall be at least 100,000 hours. The active LED area of the displays shall be 160 × 30 cm and the pixel pitch shall be 5 mm. RGB colour display shall be possible on the information screens.

Unless otherwise requested by the Authority, passenger information screens, including their frames, shall be no more than 2 metres wide. Passenger information screens shall be robust and mounted either suspended from the platform ceiling or bracket-mounted on station walls, so as to be affected to a minimum extent by train movements arriving at the platform.

Each passenger information display shall contain 2 lines of train movement information, 1 line of free-format message information and, where a digital clock is displayed, 1 line of date and time information. The information on the screen shall be configured as static, scrolling text or flashing (flash) as required.

The screen layout shall be flexible and adjustable via software according to the operator’s requirements. The operator shall be able to display train movement information or message information flexibly on the information screens according to their preference; in single, double or triple-line displays, the font size shall be automatically scaled up or down to fit the information

screen area. The operator shall 0be able to switch to single, double or triple-line displays on the information screens located in the ticket hall or on the platform at any time they wish.

All cables leading to the information screens shall be concealed, and the layout of the screens, together with the installation details, shall comply with the Authority's approval, operational and safety requirements, and coordination plans.

The interior of the information screens shall be easily accessible without the need for any dismantling work in the area where the screens are located. Components such as the LED boards, power supply, control board and communication board on the screen shall be designed with operational and maintenance ease in mind; faults occurring in these devices shall be visible as alarms on the central workstation. Station, system and display-based alarms shall be shown on the graphical display.

The screens shall be automatically switched off at the end of the operating period and automatically switched on at the start of the operating period. Settings shall be adjusted via the operator workstation. If required, the screens shall be manually switched on and off by the operator.

The information to be displayed on passenger information screens shall be as shown in the examples below:

For all station ticket halls:

Destination	**Time Remaining**	**Train Information**
[Destination Station]	2 mins	4-car
[Destination Station]	5 mins	8-line

FREE TEXT LINE (SCROLLING TEXT)

DAY/MONTH/YEAR/HOUR/MINUTE

For Intermediate Station Platforms:

Destination	**Time Remaining**	**Train Information**
[Destination Station]	2 mins	4-car
[Destination Station]	5 mins	8-line

FREE TEXT LINE (SCROLLING TEXT)

DAY/MONTH/YEARHOUR : MINUTE

For Terminal Station Platforms:

Furthermore, exclusively at terminal station platforms; taking into account double-sided operations, information screens to be installed to direct passengers alighting onto the platforms towards the platform from which the train shall depart, using data obtained from the signalling system (fully integrated), shall be as follows:

Destination	Time Remaining	Direction Information
[Destination Station]	2 mins	→
[Destination Station]	5 mins	←

FREE TEXT LINE (SCROLLING TEXT)

DAY/MONTH/YEAR HOUR:MINUTE

8.1.11.5. Content Management Server and Software

The Passenger Information System Server shall be located in the main equipment room at the Traffic Control Centre TCC.

The Passenger Information System screens on all lines shall communicate with this server via the transmission system.

It shall also communicate with the Signalling, SCADA, Workstation and Central Time System via the transmission system.

By retrieving the necessary information on all trains in operation from the signalling system and interpreting it in real time using the Central Timing System as a reference, it shall transmit the following information to the screens at stations: the destination of the next train departing from the platform and the time remaining until its departure, as well as the destination of the second train departing from the same platform and the time remaining until its departure.

Furthermore, the alarm information from the screens at the stations shall also be transmitted to the SCADA system.

8.1.11.6. Interface with Other Systems

The information screens shall operate integrated with the central clock system, thereby providing passengers with up-to-date date, hour and minute information via the screens.

It shall have an interface with the signalling system. The necessary specifications are detailed in the “System Design” section.

Alarms from the Passenger Information System shall be transmitted as data to the SCADA system.

8.1.11.7. Software and Licensing

The Communications Operator at the TCC will be able to view the messages displayed at each station via the user-friendly graphical operator screen on the workstation monitor.

The workstation shall communicate with the Passenger Information System server via the transmission system.

Via the workstation, there shall be options to display messages on individual platforms, stations, or selected groups of stations, either in full or in part; these messages, which may contain text or images, shall take priority over standard messages. Furthermore, there shall be the ability to reprogram information as required, and to adjust and input train data retrieved from the signalling computer.

Furthermore, there shall be the option to reprogram information as required.

The operator shall be able to view the layout plan of the passenger information system screens on a map via a supplementary page on the graphical display. The operator shall be able to view the real-time display information of the selected passenger information screen.

All alarms related to the passenger information system shall be displayed in the operator control software. Relevant alarms shall be categorised as priority or non-priority, and each alarm must be acknowledged by the operator. All alarms and events shall be archived on the server hosting the passenger information system's central software for a period of three months.

Screens shall be switched on and off remotely and can also be restarted at any time. Configuration settings for the passenger information screens, such as NTP server settings for the Central Time System, brightness settings, and on/off times, shall be adjusted remotely.

Should it be necessary to add a screen to a station platform or ticket hall area, the screen shall be easily added to the system via the central software, and the station time information to be displayed on the screen shall be selected. No additional licence shall be required for this.

The software shall not require a licence if it is to be used on a different computer.

8.1.12. Fare Collection System

8.1.12.1. General

Within the scope of the Fare Collection System, a system shall be designed to ensure that entry and exit to and from platforms at stations are kept under control and that passengers with

disabilities can make use of rail transport services more comfortably under the supervision of staff.

8.1.12.2. System Design

The Fare Collection System shall consist of the following units:

- Current Electronic Ticketing (card, contactless smart card, etc.) System
- Entry/Exit Turnstiles
- Accessibility Turnstiles (for each entry and exit)
- Computer Systems at Stations and the TCC
- Infrastructure for ticket vending systems

Turnstiles shall have a minimum throughput capacity of 40 passengers per minute for three-arm types and 30 passengers per minute for flap types in both entry and exit directions.

Validators for fare collection will be used on the turnstile system, and these validators will be compatible with the following access systems:

- Current Electronic Ticket (card, contactless smart card, etc.) System
- Credit Card
- QR Code
- Single-use card (One-pass, three-pass, five-pass, etc.)

The turnstile system will generally comply with the EN 50126, EN 50122, EN 50121, ISO 9001 and TSE-HYB standards.

The fare collection system to be designed at stations will transmit station-specific data to the central computer at the TCC using independent channels within the communication backbone, independently of the transmission system.

Real-time information regarding passengers passing through the turnstiles and data on the types of tickets used will be collected on the fare collection computers (local) at the stations and on the central computer of the Fare Collection System at the TCC. This shall enable the generation of all kinds of statistical reports regarding passenger movements.

The turnstiles shall be integrated into the fare collection system, operating within the same network as the fare collection computer. Each turnstile shall be monitored via the fare collection computer and SCADA using its own ID, fault information shall be retrieved, and the turnstiles shall be controlled remotely. Turnstile/Validator IDs shall be configured using a systematic coding scheme to identify stations, locations, etc.

In Station Control Rooms (SOR), there shall be a button to cut power to all turnstiles in the event of an emergency. The power supply lines for the fare collection system shall be provided via an Uninterruptible Power Supply (UPS) allocated for the Control and Communication Systems.

All three-arm turnstiles shall incorporate electromechanical counters. Thanks to these electromechanical counters, the rotations of the turnstile arms shall be counted (including disabled access turnstiles), and passenger passage records shall be maintained via the counters. If the turnstiles operate in both directions, the electromechanical counters installed on the entry or exit sides shall count passenger movements in both directions. Should the Authority request that entry and exit turnstiles be positioned separately, the counters on the entry turnstiles shall count entering passengers, whilst those on the exit turnstiles shall 3count exiting passengers.

In addition to the turnstiles to be used for the station fare collection system, standard empty conduits and/or space shall be left in cable trays for the turnstile power supply and data transmission between the computer and the turnstile, to meet the requirements for the turnstiles needed for the maximum passenger numbers in the target year.

A wireless control system shall be provided to enable remote control of turnstiles for disabled access or free passage.

For Fare Collection Systems, the data cables to be used shall be CAT6 type, aluminium foil-shielded and HFFR cables. Grounded cable connectors shall be selected.

At stations, infrastructure suitable for ticket machines (data and power cables) shall be designed for each turnstile area for passenger use. Cables shall be laid to the number of ticket machines determined during the design phase for the stations. It should be noted that the supply of ticket machines and their installation shall not be the responsibility of the Construction Contractor.

8.1.12.3. Electronic Ticket (Contactless Smart Card) System

The Electronic Ticket System shall be mounted on the turnstiles at railway stations. The system to be used shall be designed to be fully integrated with the fare collection systems of the existing passenger transport systems in the city where the system is to be installed. The ticket system shall transmit ticket reading and data to the station control computer and the central computer of the fare collection system at the TCC.

The technical specifications for validators and ticket machines shall be determined according to the fare collection concept approved fort he INRAIL Line and the applicable Administration requirements

8.1.12.4. Three-Arm Passenger Entry/Exit Turnstiles

Turnstiles shall be designed to block both sides of the transition from the uncontrolled areas to the controlled areas of the stations, thereby preventing fare evasion and ensuring that passenger

entry and exit on the railway line is controlled and orderly. The turnstiles to be used within the system shall be equipped with up-to-date electronic ticket reading units compatible with the fare collection systems currently in use in the transport systems of the city where the railway line is located.

The turnstiles shall be designed as smart turnstiles suitable for use for both entry and exit purposes . The turnstiles shall function as an entry turnstile controlled by the fare collection system for passengers entering from one direction, and as an exit turnstile allowing free passage from the other direction. When entry begins from one side of the turnstiles, the design shall ensure that a red arrow indicator on the turnstile flashes to warn those wishing to enter from the other side.

The turnstiles shall be floor-mounted. The bodies of the turnstiles shall be manufactured from stainless chrome-plated steel. The turnstiles shall be fitted with top and side access panels to facilitate technical maintenance. The turnstiles shall contain electronic circuit boards that control mechanical movements, functions and options. These boards shall be used to collect information regarding the direction of passage via commands such as “allow passage” or “deny passage” through the fare collection system, and to control the turnstile functions accordingly. Power and data communication lines shall be connected to the station turnstile computer system via cable ducts in the floor.

Each turnstile shall be equipped with a control module (controller) to monitor the remaining credit balance and passage information via the current electronic ticketing system.

A remote control unit shall be designed for each entry/exit turnstile in every turnstile zone, allowing station staff to grant free passage. This control unit shall be independent of the unit located on the disabled access turnstile and shall operate on different frequencies.

Turnstile covers shall be controlled by a different keyed lock for special service purposes; it shall not be possible to open the turnstile covers without a key. All turnstile covers shall be designed to be opened using two different types of standard keys. One of these keys shall be for the covers of compartments containing mechanical components, whilst the other shall be for the covers of compartments containing electronic cards.

Locking of the turnstile arm in the entry and exit directions shall be provided by electric solenoids. Locking shall be achieved whilst the solenoids are energised.

The turnstiles shall incorporate a counter. This counter shall count the rotations of the turnstile arm, and passenger passage records shall be maintained via the counters.

Due to the mechanical and electronic design of the turnstile, once the mechanism begins to move in one direction, it shall prevent rotation in the opposite direction. When a half-turn is initiated,

rotation in the opposite direction shall be prevented; after the half-turn, the rotation shall be completed automatically and smoothly via a special hydraulic damper mechanism. In this way, the turnstile shall be ready for the next passage after a full rotation.

Turnstile features:

Turnstile Description	Three-Arm Entry/Exit Turnstile
Subscriber reader	Electronic Ticket Reader
Ticket balance display	LCD screen displaying date, time, fare, etc.
Single-use access	With electronic ticket
Return lock	With electric solenoids
Return damping	With hydraulic dampers
Front/rear indicators	LED, green/red
Width / Height / Depth	Max. 300 mm / 1100 mm / 1300 mm
Weight	Weighs no more than what can be carried by 2 people
Material	1.5 mm thick, 304 grade stainless steel
Operating Temperature Range	-10°C to +55°C (90% relative humidity)
Power	220 VAC / 24 VDC ±20%
Power	Maximum 40 W
Arm length	Minimum 400 mm
IP Protection Rating	Minimum IP54

8.1.12.5. Accessibility Turnstiles

In the turnstile areas of stations, one accessible access turnstile shall be installed at each entry and exit point to enable passengers with disabilities to use the railway lines. The accessible access turnstiles used within the system shall have the same structure as the other turnstiles, except for the arm length, which must be 900 mm, and shall contain the same electronic cards (including the validator). The accessible access turnstiles shall operate in full compatibility with the other turnstiles.

Under normal operating conditions, the disabled access turnstiles shall remain locked at all times and shall not permit passage. The system shall be locked via electrical control and shall switch to a free-pass mode in the event of a power failure.

The locking of the turnstile arm in the entry and exit directions shall be provided by electric solenoids.

Accessibility turnstiles shall include a remote control unit enabling station staff to grant free passage to disabled passengers who are unable to pass through three-arm turnstiles and do not possess a free-pass card. Passage in both directions shall be possible via the disabled access turnstiles. The turnstile shall be designed to automatically return to a position that prevents further passage and locks once the passage process is complete.

Accessibility turnstiles shall be designed in a rounded shape to minimise the risk of accidental physical injury caused by collisions or friction from people passing through. The likelihood of any issues arising from friction during passage shall be minimised.

There shall be a marking area on the arm bearing a red disabled symbol. This symbol shall indicate both the location of the disabled access gate and the disabled access corridor. The entire body and arms shall be manufactured from stainless steel.

Turnstile specifications:

Turnstile Description	Accessibility Turnstile
Subscriber reader	Electronic Ticket, Remote Control
Ticket balance display	LCD screen, displaying date, time, fare, etc.
Single-use access	Free, with electronic ticket
Return lock	With electric solenoids
Damping	With hydraulic dampers
Front/rear indicators	LED, green/red
Width / Height / Depth	Max. 900 mm / 1100 mm / 1300 mm
Weight	Weighs no more than what can be carried by 2 people
Material	1.5 mm thick, 304 grade stainless steel
Operating Temperature Range	-10°C to +55°C (90% relative humidity)
Power	220 VAC / 24 VDC ±20%
Power	Maximum 40 W
Arm length	Minimum 850 mm
IP Protection Rating	Minimum IP54

8.1.12.6. Flap-type passenger entry/exit turnstiles

The turnstile flaps shall be of the ‘hidden gate’ type, retracting into the body. The flaps shall open and close via motorised movement.

The gate flaps shall operate in a synchronised manner. The flaps used shall be constructed to withstand impact from passengers during passage, featuring a durable design and dimensions compliant with industry standards. The flap thickness shall be at least 15 mm.

The wings shall be designed so that during opening and closing operations, they do not strike the turnstile body with force, do not cause any vibration or damage to the internal turnstile equipment or connections, do not lead to turnstile malfunctions in the long term, and do not cause harm to passengers passing through. The design shall not affect the passenger throughput rate, which must be a minimum of 30 passengers per minute under all circumstances.

The turnstiles shall be designed to prevent unauthorised passage to the greatest extent possible. Should unauthorised passage be detected, an audible alarm shall sound at a volume audible from the security point located in the turnstile area. Once a passenger has swiped their card through the turnstile, the system shall not permit the following passenger to pass without their card being swiped; however, if a valid card is swiped, the gate wings shall remain open to allow the passenger immediately behind to pass (For passengers passing consecutively at intervals of no more than 1 second, if two valid cards are read in succession, the wings shall remain open and shall not perform an unnecessary closing operation). If new passage authorisations are received after the gate has opened for passage, the flaps shall remain open until the consecutive passages are completed; if there is a gap between passages, or if an invalid card is swiped, or if an entry is made without swiping a card, the flaps will close automatically.

Flap turnstiles shall be equipped with the necessary infrastructure for either Normally Open (NO) or Normally Closed (NC) operation. The Normally Open and Normally Closed options can be configured and monitored via the fare collection computer or SCADA/ECS.

Turnstiles that permit exit operations may also be used as entry turnstiles when required; they shall be designed with validators to operate as either entry-only or exit-only turnstiles as needed. There shall be one validator per turnstile for both entry and exit turnstiles.

The disabled access turnstiles used within the system shall have the same structure as the other turnstiles and shall incorporate the same devices/cards (including the validator). The disabled turnstiles shall operate in full compatibility with the other turnstiles, and one validator shall be supplied and installed for each disabled turnstile. Accessibility turnstiles shall incorporate a remote control unit to allow for free passage.

Furthermore, wall-mounted or freestanding Refund Validators, in the quantities specified in the project, will be provided for use in distance-based fare collection within the turnstile areas. The locations of the Refund Validators shall be specified by the Authority/Operator during the installation phase of . Infrastructure (power/data cables, conduits, etc.) shall be designed for the Refund Validators.

In each turnstile group, one turnstile shall be designated as a Control Validator, enabling the verification of the remaining credit balance and access information on the Card or Smart Contactless Electronic Card.

All cables within the turnstile frames shall be routed through cable ducts; no unstructured layout shall be created inside the turnstile. Flat cables within the turnstile shall be housed within shielding and protected against electromagnetic interference.

Power supply to all turnstiles and validators, as well as data communication links to the station turnstile computer, shall be provided via suitable cable ducts running beneath the floor/surfacing.

General Characteristics of Flap Turnstiles:

- The minimum and maximum temperature range for operation, transport and storage shall be -10 °C to +55 °C; the minimum (maximum) relative humidity during operation shall be 90%.
- It must have an operating voltage of 220 VAC / 24 VDC ±20% and a maximum power consumption of 40 W. An optional electronic counter may be used.
- The maximum dimensions shall be 300 mm (width) / 1100 mm (height) / 1800 mm (depth).
- It shall be light enough to be carried by a maximum of two staff members.
- It shall feature two-way access and shall emit an audible warning in the event of unauthorised entry.
- In the event of an emergency, the system's power can be cut off to allow the turnstile to open in both directions.
- It shall be capable of being easily integrated via dry contacts with any type of access control device, such as a card reader, fingerprint or facial recognition system, biometric reader, remote control or button.
- In accordance with the CE (Conformity European) marking requirements, it shall comply with health (ensuring electromagnetic limits are not exceeded) and safety (preventing contact with voltage points at levels that could affect humans) standards and shall hold a Certificate of Domestic Origin and a TSEK (Certificate of Conformity to Standards).
- It shall have a minimum IP54 protection rating.

8.1.12.6.1. Turnstile Control Unit

The control unit shall feature a time-out function. With this feature, if passage is not completed within the time-out period after the gate (flaps) has opened, the passage is cancelled and the gates (flaps) close. This duration can be adjusted parametrically within the range of 8–15 seconds.

The flap turnstile system, whilst normally used in the closed position, shall have the software and hardware capacity to allow at least 30 passengers per minute in the entry direction (30 passengers/direction*min).

To monitor the remaining credit balance and passage information via the electronic ticketing system at stations, each turnstile group shall be designed to include a control module (electronic control unit) in one of the turnstiles. Furthermore, each entry/exit turnstile in every turnstile zone shall incorporate a remote control unit enabling station staff to grant free passage. This control unit shall operate independently of the unit located on the disabled access turnstile and shall be configured to operate on different frequencies.

8.1.12.6.2. Sensors / Detectors / Control Unit

The control system for the turnstile shall be managed by the turnstile control board.

Communication between the validator and the SCADA system can be carried out via these ports.

BLDC (brushless) motors shall be preferred for their long service life.

The flap turnstile system shall be equipped with the necessary and sufficient number of sensors to ensure high reliability and efficiency, enabling it to operate with a passage accuracy rate of at least 99.98%. The sensors shall:

- Track the movements of passengers passing through the turnstile passageway,
- Track the direction of passage/movement,
- Be capable of tracking movement speed,
- If the gates are in the closed position (Normally Closed position), they shall open when a valid (validated) access request is detected;
- If the wings are in the open position (Normally Open position), upon detecting a valid (validated) passage request, they remain open without performing a closing and reopening movement, and
- to allow at least 30 passengers to pass through per minute

and the turnstile software and hardware shall be designed to operate in this manner.

Passengers with luggage shall be able to pass through the turnstile corridor with their luggage as a single passenger; they shall not be detected as two or more passengers. Sensors shall be used in sufficient numbers and of a design capable of accurately and quickly detecting such passages with luggage.

8.1.12.7. Body

Turnstile casings, floor mounting brackets and other components attached to the turnstile shall be made of impact-resistant materials and fittings. Turnstiles shall comply with industry standard dimensions and construction.

Turnstiles shall be mounted to the floor using a special mounting bracket. The body sheet metal thickness of the turnstiles shall be at least 1.5 mm, manufactured from stainless chrome steel. The turnstiles shall be fitted with access hatches to facilitate technical service interventions, and these hatches shall provide full accessibility (serviceability) to all equipment, cables, screws, etc. within the turnstile.

All screws and nuts (fibreglass-reinforced) used within the frame shall be galvanised or stainless steel. The turnstile cover design shall be such that, whilst maintenance or fault-repair work is being carried out on it, it does not interfere with the operation of the other turnstiles, ensuring maintainability and practicality.

The validators to be mounted inside the turnstile shall be designed in such a way that they do not appear to have been added to the turnstile at a later date, nor do they protrude from the turnstile, creating an appearance that disrupts the integrity of the unit (a patchwork appearance).

8.1.12.8. Warning Lights

Warning lights located at the turnstile entrance shall indicate the turnstile’s operational status, usage condition, faults, emergency situations, etc.

8.1.12.9. Electrical Components

In the event of a power cut, the UPS shall activate and the turnstiles shall continue to operate. If power is cut to a single turnstile, its arms shall remain closed; however, if power is cut to all turnstiles in the relevant group, all turnstile arms shall remain open.

The equipment shall not be directly exposed to mains power to prevent it from being affected by power surges.

The control system shall be designed to eliminate the risk of electric shock. Necessary measures shall be taken to ensure that passengers are not exposed to electric shock through contact or arcing whilst passing through. Turnstiles shall be fitted with residual current devices (RCDs) or overcurrent-protected RCDs, and proper earthing in accordance with standards shall be provided to protect passengers and staff from relevant electrical hazards.

In the event of a communication failure between the fare collection computer and the turnstile, data shall be retained on the validator system; once communication is restored, this retained data shall continue to be transferred without loss.

The industrial photoelectric sensors used shall be of the connector type and shall allow for easy intervention in the event of any fault.

8.1.12.10. Emergency Mode

In emergency mode; when the turnstile(s) are controlled via command signals or codes from the SCADA system or the turnstile computer, the turnstile gates shall open and remain open for passage until this signal is withdrawn, and all turnstile functions shall be blocked.

8.1.12.11. Turnstile- -Computer Systems

The data from the fare collection system terminals located at the turnstiles shall be transmitted to one industrial computer each, installed in the fixed-type cabinets in the station communication room or, if available, in the turnstile equipment room, depending on the number of turnstile zones at the stations and the distances between them. The industrial computers at the stations shall run station fare collection software and shall communicate with the station fare collection turnstile terminals via a data communication line. Information collected from the fare collection system terminals at the turnstiles can be transmitted to the TCC via the Transmission System.

The industrial computers used at the stations shall be of a design suitable for the station's specifications and the communication cabinet, and shall be up-to-date in terms of hardware and software features. The motherboard within the industrial chassis shall be powered by a suitable power supply unit. The system power supply shall be provided via the uninterruptible power supply allocated to the station's control and communication systems, in accordance with the specifications of the industrial computer.

8.1.12.12. Ticket Vending Machines Infrastructure

The design shall take into account that the infrastructure for the power and data cables (cables, cable ducts, etc.) for the Ticket Vending Machines to be installed at the stations shall be supplied and installed by the Construction Contractor.

8.1.12.13. Interface with Other Systems

Alarms from the Fare Collection System shall be transmitted as data to the SCADA system. The SCADA section of the document provides the minimum I/O lists required for the system.

An interface with the time system shall be provided.

All turnstiles can be controlled individually and/or collectively via the SCADA system (station or TCC).

Information to be monitored and functions to be controlled in the Fare Collection system (and in SCADA):

- The entry and exit modes of the turnstiles; these can be monitored by the fare collection computer and SCADA. Should the Authority require it, the entry and exit modes (Free, Paid, Blocked, etc.) can be easily changed via the fare collection computer (and SCADA).
- Faults in the turnstile system shall be transmitted to the fare collection system computer (and SCADA); this information shall contain sufficient detail to identify and address the fault.
- Information from the warning lights shall be transmitted to the validators, ensuring that the relevant message (icon, pictogram, etc.) is displayed on the validator screen.
- Turnstiles shall provide an exit option in emergencies when released by station staff. The operational status of each fare collection turnstile can be reported continuously via the SCADA system. Status information regarding the turnstiles for passengers shall be displayed on panels at the turnstile entrances and exits. This information shall indicate whether the turnstiles are open for use.
- The turnstiles shall be equipped with electronic control units that allow the mechanical movements, functions and options to be monitored, adjusted and modified. These units shall use the fare collection system to issue commands such as ‘grant access’ or ‘deny access’, collect data on the direction of passage, and control the turnstile functions accordingly.

8.1.12.14. Data Flow and Reporting

The Passenger Passage Information and Reporting programme shall include information such as “malfunction or power cut”, “dwell time”, “active operating time”, “turnstile reset”, etc., on a turnstile-by-turnstile basis, and shall be capable of generating daily, weekly, monthly and annual reports on these matters.

The 24-hour data of the Passenger Passage Information and Reporting programme shall have an accuracy rate of at least 99.98%.

Verification of this accuracy requirement for the system shall be carried out during the construction phase at as follows: At any three stations selected by the Authority, for a period of four weeks, the mechanical counters of all turnstiles shall be reset every morning before operations commence; at the end of the day, when operations cease, the counter readings shall be taken again and the difference calculated. This information shall be recorded in a log for each turnstile. At the end of the 4-week period, the results shall be compared with the 4-week report from the Passenger Transit Information and Reporting programme. Here, the mechanical counter data shall be accepted as the primary accurate data. The difference shall be 0.02% or less. Comparison checks shall be carried out weekly on Mondays for the previous week’s data, and in the event of a failure, the 4-week period shall be restarted from the first day of the first week. A period during which successful comparisons can be made for four consecutive weeks without interruption (28 days) shall demonstrate that the 99.98% accuracy target has been achieved.

These tests shall continue until success is achieved. Turnstiles operating solely as exits are not included in the scope of these tests.

8.1.12.15. System Reliability and RAMS

In the fare collection system, the accuracy of transit data shall be at least 99.98%. The redundancy incorporated into the system architecture and equipment design shall ensure operational capability even under low-performance conditions down to the individual (single) turnstile level, without causing any loss in fare collection capacity. The system design methodology shall comply with the EN 50126 standard.

The system shall not pose any health or safety risks to passengers using the public transport system, including EMI arising from smart card readers, and shall comply with the EN 50122 standard.

The Fare Collection System shall comply with the conditions specified under the EMC standard EN 50121.

The system shall be designed to prevent situations such as data loss or data corruption that may occur during operation due to power surges or power cuts, water and oil leaks, dirt, corrosion and similar causes.

8.1.12.16. Software and Licensing

The workstation to be installed at the Traffic Control Centre (TCC), together with the software running on it, shall ensure the performance of the functions specified below, covering all stations.

- All types of toll charges, credit deductions, and fare classifications (such as full-fare, student, and similar categories) can be easily set up and updated.
- Real-time passenger data for each turnstile, along with the ticket type used for these journeys (…Card, Smart Contactless Electronic Card, Credit Card, QR reader, etc.), and statistical data based on ticket fares and fare categories shall be collected in the database in real time. Furthermore, real-time information regarding passenger movements shall be displayed.
- The software shall include functions to provide journey analysis reports based on entry and exit data, taking into account that refund validators can also be integrated into the system.
- The software shall include authorisation features, and the necessary menus shall be available to retrieve the required reports.
- The database file shall be backed up continuously and securely.
- Software updates and fare adjustments for all turnstiles can be carried out remotely.

- Reports showing data for a specific time or time period can be provided, upon request, in a familiar and easily readable file format (Excel, Word, etc.).

The software to be supplied (operating system, office programmes, etc.) shall be delivered together with the relevant licences. The Passenger Transit Information and Reporting Programme shall be supplied to the Authority together with the licensed software. Furthermore, the system shall be capable of transmitting real-time transit data to a computer located at the Operator Organisation's headquarters or to another separate computer specified by the Authority. It shall be noted in the design that the provision and installation of this specified computer and the communication links to it shall not fall under the responsibility of the Construction Contractor at . However, the system shall be capable of performing this function.

8.1.13. Fire Detection and Alarm System

8.1.13.1. General

The Fire Detection and Alarm System shall be designed as a comprehensive system that fulfils the fire safety requirements across all areas of the stations and external structures (transformer buildings, generator buildings, operations buildings, etc.), performing fire detection, alarm activation, control and communication functions.

The design objective of the Fire Detection and Alarm System is to detect the presence of fire or smoke, provide early warning via appropriate visual and audible alarms, and activate evacuation systems.

The Fire Detection and Alarm System shall comprise fully automatic addressable fire alarm panels, along with the sub-units and control equipment monitored by these panels.

The Fire Detection and Alarm System comprises workstations, fire alarm panels, detectors (optical smoke, heat, combined (smoke and heat), beam), linear heat detection system (LHD), fire alarm push-buttons, strobe lights, sirens, strobe sirens, addressable loop input/output boxes/devices (IOM monitoring modules), addressable control modules, alarm indicators, detection loops, etc. The system shall consist of the above equipment.

The equipment in the Fire Detection and Alarm System shall be of the electronic addressable type.

The Fire Alarm Panel (FAP) shall be of a modular design and shall enable the monitoring of alarms and faults on the electronically addressable detection loops.

8.1.13.2. Standards

The system shall be designed in accordance with the current version of the Regulation on Fire Protection of Buildings.

The design of the system and its components must comply with the current versions of the TS CEN/TS 54-14 and TS EN 54 standards.

In cases of inconsistency between standards, the Regulation on Fire Protection of Buildings shall be taken into account.

Railway systems where the entire route and the majority of stations are located underground or in tunnels shall require special design requirements; where the specified standards do not provide sufficient clarity, reference shall be made to EN and NFPA standards.

8.1.13.3. System Design

Each station and all buildings and premises requiring fire safety shall be equipped with a sufficient number of fire alarm panels (FAP) in accordance with architectural and technical requirements. These panels shall continuously monitor all relevant areas within the building using equipment such as point detectors, push-buttons, and entry/exit modules, thereby managing the system and providing all information in real time. The panels shall display this information (faults, alarms, warnings, etc.) visually to operators on workstations.

Automatic fire detectors shall be of the electronically addressed type and shall possess an algorithm-based decision-making mechanism capable of distinguishing and preventing conditions that could lead to false alarms under normal conditions.

The panel processor shall be capable of scanning all circuit components within the control loop within a timeframe of 1 ms to 10 seconds.

On the relevant microprocessor, responses to alarms from various combinations of detectors, flow switches or manual call points shall trigger the functions shown below, according to the specific requirement.

- Alerting station personnel,
- Alerting the SCADA Operator at the Traffic Control Centre (TCC) via the SCADA System,
- If station staff do not respond, to ensure that the SCADA system initiates evacuation via the relevant systems by sending a ‘no alarm received’ signal to the SCADA system,
- Activate the fire-fighting equipment,

The signal regarding the evacuation of the station shall be broadcast via the public address system. In areas where the audible alarm system is not sufficiently audible, additional audible alarm signals shall be provided in conjunction with flashing warning lights.

All statuses of the fire detection and alarm system shall be continuously monitored from the control rooms (SOR, DOR) via workstations.

All cables comprising the Fire Detection and Alarm System, and all lines used for communication with remote control and monitoring centres, must be kept under constant surveillance to detect faults such as breaks, short circuits and earth faults.

All devices belonging to the Fire Detection and Alarm System must be accessible for periodic testing and maintenance (to ensure ease of maintenance). In this regard, all necessary measures shall be taken during the design phase.

The Fire Detection and Alarm System shall monitor the alarm, fault and activation statuses of all gas-based fire suppression systems within the railway line.

The Fire Detection and Alarm System shall monitor the alarm, fault, status (manual/automatic) information and activation statuses of equipment belonging to the Fire Protection Systems.

The Fire Detection and Alarm System shall monitor the alarm, fault and activation statuses of equipment belonging to the Linear Heat Detection (LHD) Systems.

General faults and alarm conditions occurring in pre-defined fire zones, alarm conditions in fire suppression systems, and LHD general alarms can be monitored from the Traffic Control Centre (TCC) via the SCADA System.

Table 8.12 : Distribution of Fire Detection and Alarm System Equipment by Location

Area	Optical Smoke Detector	Heat Detector	Combined Detector	LHD System	Fire Alarm Button	Strobe Siren	Strobe Light	Siren	Beam Detector
Washroom		X							
Emergency Escape Staircase	X								
Battery Rooms			X					*	
Lift Shaft	X								
Workshop Building							X		X
Unit Workshops	X							*	
Baby Care Rooms	X						X		
Storage Rooms	X							*	
Drainage/Wastewater Pump Room		X				X			
Training/Meeting Room	X							*	
Electrical / Switchboard / DC Isolator Rooms			X					*	
Fibre Optic Room			X					*	
GSM Room			X					*	
Communications Room									
Ventilation Room			X			X			
Toilet		X					X		
Station Ventilation Fan Room			X			X			
Station Control Room			X			X			

Area	Optical Smoke Detector	Heat Detector	Combined Detector	LHD System	Fire Alarm Button	Strobe Siren	Strobe Light	Siren	Beam Detector
Generator Room			X			X			
Cable Shaft				X					
Controlled / Uncontrolled Areas	X				X		X		
Prayer rooms	X					X			
Offices	X								
MV/LV/Traction Power Equipment Room			X		X	X			
Traffic Control Centre (TCC)			X						
PSDS Panel Room			X					*	
Platform	X				X		X		
Platform Level				X					
Platform Connecting Tunnels	X				X		X		
Staff Break Room	X						X		
Staff Changing Room	X						X	*	
Medical Room	X						X		
Signalling Room									
Technical Area Corridor	X				X		X		
Cleaning Room		X						*	
Meeting Room	X						X		
Turnstile Equipment Room			X					*	
Tunnel Ventilation Fan Room			X			X			

Area	Optical Smoke Detector	Heat Detector	Combined Detector	LHD System	Fire Alarm Button	Strobe Siren	Strobe Light	Siren	Beam Detector
Fire Safety Lobby	X				X**		X		
Fire Pump Room		X				X			
Storage Rooms	X							*	
Escalator	X***			X					
Escalator Control Room			X					*	

* To be installed if the sound level limits specified in the regulations are not met.

** To be installed on both the inside and outside of the entrance door.

*** To be installed only in the upper shaft.

In areas where gas fire suppression is to be used, at least two detectors shall be installed. One of the detectors shall be set to detect heat, and the other to detect smoke.

In the design, where a public address system with a loudspeaker is installed, a strobe light shall be provided; in areas without a loudspeaker, either a siren or a strobe-equipped siren shall be installed, depending on the ambient noise level.

8.1.13.4. Detection Loop

A detection loop shall be designed to cover only a single floor. The length of the detection loop shall not exceed the maximum loop length specified in the product's catalogue. A loop length shall support at least 2,000 metres of 0.8 mm diameter cable.

All devices within the loop shall automatically register their addresses with the control panel without the need for any dip-switches, rotary switches or similar coding elements.

In each detection loop, a reserve of 20% of the capacity shall be maintained, both in terms of address and power.

Monitoring and control functions within the Fire Protection System and Linear Heat Detection System can be carried out via Addressable Monitoring Modules (IM) on the detection loops . The gas extinguishing system shall be designed to also perform monitoring and control functions.

The circuits shall be capable of operating in a dual-redundant configuration to maintain functionality in the event of a fault.

8.1.13.5. Fire Zones

The general design of the fire zones shall comply with the relevant provisions of the Regulation on the Protection of Buildings against Fire or with requirements set out in other similar international standards.

Zones shall be arranged in accordance with the following principles:

- Each station floor shall constitute a fire zone.
- The escalator area shall constitute a completely separate zone.
- The areas beneath the platforms shall constitute a single fire zone.
- Each platform shall constitute a separate fire compartment.
- Service access levels shall constitute their own independent fire compartments.
- Facility intermediate levels shall constitute their own independent fire zones.
- The traction power area and station transformers shall constitute their own independent fire compartments.
- Facility and equipment rooms (excluding transformers) shall constitute a single fire compartment.

During zoning, the mechanical zones of the Wet Fire Extinguishing System shall be taken into account.

The design shall incorporate a zoning system based on an information management system, which can be easily transferred to a computer and follows a logical sequence.

8.1.13.6. Station Main Fire Alarm Panel

The station fire alarm panel shall be installed in the Station Control Room. The panel shall be positioned where personnel entering the room can easily see it; it shall be of an addressable type and shall have a ‘Stand-alone Operation’ function.

The Station Fire Alarm Panel’s detection loop capacity shall be modular, with a minimum of 4 detection loops, tailored to the requirements of the station and other relevant areas, and one of the detection loops shall be kept as a backup at all times.

The station fire alarm panels shall be capable of monitoring and managing all devices connected to the detection loops within the station, as well as devices connected to the detection loops of Remote Fire Alarm Panels. Alarm and fault information from any device connected to a panel loop shall be relayed to the Station Fire Alarm Panel in the same format. A MODBUS output via

direct TCP/IP can be provided through the panel. Theoretically, up to 250 elements can be connected to a single loop.

The Station Fire Alarm Panel (FAP) shall incorporate the necessary structural provisions to allow devices to be easily removed, and to enable the addition of new devices to the system—whether permanently or temporarily—or the replacement of existing devices with others.

New devices can be easily added to the existing detection loop. Sensors or input/output devices can be activated in any detection loop by means of on-site programming.

The panel will feature an LCD screen. Information regarding alarms, faults, warnings and isolation statuses shall be displayed in separate tabs on the screen. There shall be a mute/activate button to enable or disable the sirens, and an off/on button to isolate the system in specific situations. To temporarily isolate the connection to the control centre or the fire brigade during maintenance, the panel will feature a communication on/off button, and its active status shall be indicated via a lighted indicator. There shall be a dedicated button on the panel to manually switch between day and night modes.

The panel shall have at least two dry contact auxiliary output devices. It shall be possible to increase the panel's capacity by providing additional output device cards or relay modules.

As standard, there shall be a printer on or next to each panel. All printed messages can be stored in the processor's memory for at least 24 hours.

Functions of the Station Fire Alarm Panel such as reset, equipment isolation and programming shall be restricted by different user passwords. However, authorised personnel shall be able to access these menus. The keyboard shall be suitable for password entry.

The Station Fire Alarm Panel shall be capable of self-diagnosis and shall be designed to alert the operator to any device failure or functional defect in any part of the system, ensuring that fire alarms are not confused with fault warnings. It shall alert operational staff in the event of a failure or disconnection of any device or audible warning system.

Provision shall be made to temporarily isolate any individual circuit device or group of devices, and the panel's main display shall issue a warning until all devices return to normal operating conditions. When any device is isolated, the panel status shall be displayed as 'device isolated' on the LCD screen.

The panel shall be equipped with 'watch-dog' special control circuits to allow all microprocessors, logic and sample circuits to be monitored at any time as required. In the event of a fault, the microprocessor performing continuous monitoring shall activate the necessary automatic restart function to return the system to normal operating conditions.

The panel shall have a modular design. The modules within the panel, along with the user display and control units, shall be mounted in a configuration that is easily accessible and maintainable.

All panels shall be compatible with the necessary infrastructure for network communication. Where multiple panels are used, the fire alarm panel shall be equipped with a communication module to enable local network connectivity with other controls. This communication may be provided via a fibre optic or RS 485 communication module. The fire alarm panel shall be capable of data-based communication with third-party devices via a BACNET or MODBUS communication bridge.

The panel shall be of original factory manufacture, complete with corrosion-resistant painted internal components. Access to the interior of the panel shall be possible via a lockable hinged front cover.

Internal connections within the panel shall be made properly using suitable connection equipment.

The station fire alarm panel shall be capable of operating continuously and independently in the event of a SCADA system failure.

The Control Panel shall comply with the specifications and performance criteria set out in the EN 54-2 and EN 54-4 standards.

8.1.13.7. Remote Fire Alarm Panel

A Remote Fire Alarm Panel shall be used in situations where the detection loop length of the Main Fire Alarm Panel is insufficient to cover the relevant area (e.g. in dual-concourse stations, etc.). The technical specifications of the Remote Fire Alarm Panel shall be fully compatible with those of the Station Fire Alarm Panel.

8.1.13.8. Fire Alarm Panel Power Supply and Power Source

All fire alarm panels shall be equipped with their own power supply and maintenance-free, sealed batteries.

The power supply shall be equipped with the following protections.

- Against overvoltage from the mains
- Protection against power supply short circuits
- Against battery reverse connection

The power supply shall have voltage regulation, and the system shall be normally powered even when the batteries are not in the circuit.

All Fire Alarm Panels shall be powered by a UPS designated for Communication and Control Systems. Furthermore, in the event of a power cut, the fire alarm panel shall be equipped with sealed, maintenance-free batteries capable of sustaining all operations for 30 minutes after having maintained normal operation for 24 hours. The batteries shall comply with the EN 54-14/6.8 standard.

The batteries shall be maintained in float charge. If the battery voltage drops below a pre-set level, this shall be identified as a power supply fault. When the batteries are activated, this shall be indicated on the panel by an audible and visual alarm.

The panel shall include a “power supply fault” indicator displaying battery, charger, or power supply faults or malfunctions.

The panel shall be constructed to withstand fluctuations of ±10% of the nominal 230 V AC operating voltage. The status and connectivity of each battery, as well as the main power supply connection, shall be monitorable. In the event of abnormal operating conditions or an interruption in the main processor’s operation, an error warning shall be issued.

The charging unit shall be capable of charging a discharged battery to 80% of its full charge capacity within 24 hours, and this process shall be possible whilst the system is operating normally and under “peak” load conditions.

The charging device shall have a 10% reserve capacity to accommodate any increase in demand.

8.1.13.9. Fire Alarm Panel Functional Requirements

The alarm triggered by a detector shall be indicated visually by a red light clearly visible on the front of the panel, bearing the word “FIRE”, and simultaneously by an internal audible alarm. This condition shall remain active until the panel’s “RESET” function is activated.

In the event of an alarm, if the incoming alarm is not acknowledged via the Station Fire Alarm Panel and the Station Fire Alarm Workstation within the timeframe specified by the Authority, the Station Fire Alarm Panel shall send an “alarm not acknowledged” signal to the SCADA System. Consequently, a general evacuation warning shall be transmitted to the Public Address System via the SCADA System, thereby automatically broadcasting the station evacuation announcement. The Station Fire Alarm Panel (FAP) shall transmit regional fire alarm, fault, and device isolation warnings, as well as fire protection system information, to the SCADA System.

In the event of any fault, an appropriate LED displaying “FAULT” shall illuminate and an internal audible alarm (buzzer) shall sound to alert the operator.

The panel shall record all operations and fire alarms. It shall store a chronological list internally and be capable of printing this list when required. The panel shall provide the ability to print a

checklist of devices in “FIRE” status, devices in “FAULT” status, “ISOLATED” devices, and devices “REGISTERED” in the system.

A function shall be provided to test all devices sequentially without triggering the alarm.

All Fire Detection and Alarm System functions can be programmed via a portable maintenance computer in addition to the panel. Using the maintenance computer, it shall be possible to enter information regarding sensor types, the detection loop to which they are connected, and all other relevant details; add new sensors or equipment to the loop; programme audible and visual output devices; and programme operational scenarios for fire suppression systems.

8.1.13.10. Audible Alarms

The Public Address System shall be the primary means of alerting technical staff and passengers in the event of a fire or other incident. If the sound level produced by the Public Address System does not meet the limit values specified in the regulations, audible alarm/warning devices shall be used within the premises.

Furthermore, flashing sirens shall be installed in large, noisy rooms such as the MV/LV/Traction power equipment room, generator room, pump rooms and fan rooms.

All audible alarm devices shall have a sound intensity of at least 95 dBA and three distinct tones. In this context, the sound produced shall be distinct from the sound of any other equipment in the building and shall be distinguishable from all other sounds.

The actual number and locations of these devices shall be determined based on sound level analyses. All audible alarm devices shall be capable of transmitting both the fire signal and the fire evacuation signal.

Fire alarm sirens shall have an IP65 protection rating.

A siren module shall be used as an intermediate unit for control on the loop circuit.

The fire alarm must be capable of being mounted on a wall or ceiling to provide visual warning in accordance with the EN 54-23 standard and audible warning in accordance with the EN 54-3 standard. Accordingly, the product must have models that can be mounted on walls and ceilings.

Different sound tones must be adjustable via the DIP switch on the unit.

It shall comply with the features and performance criteria specified in the EN 54-3 and EN 54-23 standards.

8.1.13.11. Fire Alarm Flasher

In technical corridors and passenger areas equipped with a fire alarm button, a fire alarm strobe light shall be installed at an appropriate height in line with the button.

In the event of a fire in any room opening onto the corridor, the flashers located in the relevant corridor shall be activated. Fire alarm flashers installed in public areas shall only be activated when the scenario is triggered.

A siren module shall be used as an intermediate unit for monitoring on the loop circuit.

Fire alarm strobes shall provide a minimum luminous intensity of 1 candela in accordance with EN 54-23.

Fire alarm strobe lights shall have an IP65 protection rating.

8.1.13.12. Repeater Panel – Remote Assembly Points

Repeater panels shall be installed in locations that shall enable relevant personnel to remotely control the fire panel from a location normally used as a remote assembly point or Station Control Point.

This repeater panel shall be able to indicate which device is in a ‘fire’ or ‘fault’ condition, as well as the relevant fire zone. Repeater panels shall be equipped with control mechanisms to perform the functions of the main panel at a remote location.

Controls shall include silencing the alarm, reporting the alarm, displaying received alarm signals, and resetting the panel to its normal state. Only the “reset” function shall be protected by a key.

The presentation of information, content and controls shall be similar to that of the station fire alarm panel. The repeater panel shall be able to monitor the equipment monitored and controlled by all panels at the station and perform the specified control functions.

The repeater panel shall be equipped with an internal bell that operates in all fire and fault conditions, as well as the capability to activate monitored alarm sound devices. The bell shall be audible from a distance.

The repeater panel shall draw its power from the UPS source allocated for communication and control systems.

The repeater panels shall be certified to EN 54-2.

8.1.13.13. Fire Alarm Button

Fire alarm buttons shall be installed along evacuation routes in the stations. Fire alarm buttons must be positioned such that the horizontal access distance from any point on a floor to any fire alarm button on that floor does not exceed 60 metres. On routes used by disabled persons, this distance shall not exceed 30 metres. Disabled toilets shall be fitted with an Emergency Pull-Cord Call/Warning Button and an addressable flashing light above the door. This button shall be connected to the fire detection system's monitoring module. Calls can be monitored via the fire alarm panel, repeater panel and graphical monitoring software.

The buttons shall be positioned at a height of between 110 and 130 centimetres above the floor and shall be placed at strategic points throughout the station area so that they are clearly visible from the front and, in practice, from the side. The selected positions shall be arranged so that they are visible from all exit routes.

The buttons shall be positioned in staff areas, next to public doors, and in such a way that they do not close when the door is opened.

If conventional buttons are used, they must be used in conjunction with an addressable monitoring module.

The addressable button shall have a transparent front cover that opens upwards. Addressable buttons shall be of the type operated by manually pressing a plate located beneath the front cover. This lower plate shall be made of shatterproof flexible material; it shall not require replacement each time it is pressed. The addressable button shall be equipped with a reset mechanism operable by a key. The button's operating method shall be indicated on its surface. No further action shall be required to trigger a fire alarm.

The button housing shall bear the word "FIRE" (in both Turkish and English) in indelible black lettering. The letters shall be 10 mm high. After activation, an indicator of a different colour to the cover shall appear to indicate that the button has been activated.

Where buttons are used in open areas or enclosed areas requiring protection, they shall be of IP65 protection class.

8.1.13.14. Monitoring Modules (IM)

Monitoring Modules (IM) shall be used to connect warning devices requiring external power (e.g. sirens with flashing lights) to the fire detection circuit, in addition to audible/visual warning devices (sirens, flashing lights) that can be directly connected to the detection circuit and draw the necessary power from it.

Monitoring Modules (IM) shall be equipped with contacts capable of monitoring or activating external equipment connected to the detection circuit.

The power required for Monitoring Modules to activate external equipment shall be supplied from an uninterruptible power supply allocated for communication and control systems.

Monitoring Modules (IM) shall be used in conjunction with the following units:

- Audible/visual warning devices requiring external power,
- Linear Heat Detection System
- Fire Protection System
- Gas Extinguishing System
- Commercial Area Fire Detection and Alarm System

Monitoring Modules (IM) shall enable the Fire Detection and Alarm System to monitor the alarm and fault statuses of linear heat detectors separately.

As part of the Fire Protection System monitoring, the following information shall be transmitted to the Fire Detection and Alarm System via Monitoring Modules (IM).

- Fire pump (including jockey pump) on/off status information
- Fire pump (including jockey pump) fault information
- Water tank level information (there shall be 4 levels: very low, low, high, very high)
- Flow switch and pressure switch status information
- Status information for all monitorable valves, including those connected to Local Water and Sewerage Authorities, excluding test and drain valves

Information regarding the gas fire suppression system shall also be transmitted to the Fire Detection and Alarm System via Monitoring Modules (IM).

Only the IOM module shall be designed for areas protected by the gas fire suppression system. No fire detection and alarm system equipment shall be installed within these areas.

8.1.13.15. Relay Module (RM)

Relay Modules (RM) shall be used to connect warning devices requiring external power—other than audible/visual warning devices (sirens, flashing lights) that can be connected directly to the detection loop and draw the necessary power from the detection loop—to the fire detection loop.

8.1.13.16. Input/Output Modules (IOM)

The NA/NK (Normally Open/Normally Closed) position may be selected via the cable terminal input on the module.

It shall comply with the characteristics and performance criteria specified in the EN 54-18 standard.

Depending on the location where it is to be used, the number of inputs/outputs and the module's specifications shall be determined (e.g., 1 input + 1 output, 3 inputs + 2 outputs, 4 inputs + 4 outputs, 8 inputs + 8 outputs, etc.).

This depends on the location where the module shall be used. It is generally suitable for technical room monitoring and control points (such as motorised fire dampers and smoke extraction fan monitoring and control).

8.1.13.17. Isolators

Isolators (circuit disconnectors) shall be used as protection against short-circuit faults in data loop cables.

To protect the fire alarm panel against short-circuit faults, the first and last equipment in each detection circuit must always be an isolator.

Should detectors (sensors) or Monitoring Modules (MM) also possess circuit-disconnecting functionality, the distribution of disconnectors within the detection circuits shall be arranged with this in mind. In all cases, there shall be one isolator for every 20 pieces of equipment in the detection circuit.

At the discretion of the management, all equipment to be used in the system may be selected with built-in short-circuit isolators for ease of operation and maintenance.

8.1.13.18. Detectors (Sensors)

Optical smoke, heat or combined (heat and smoke) detectors shall be used in the design, in accordance with the area of use and environmental conditions. Beam detectors shall be used in areas such as station atriums with high ceilings.

Detectors shall be capable of being mounted and removed from the detector base without the use of special tools. Detectors shall be designed to allow cleaning without removal in the event of contamination, or shall consist of removable parts.

The control panel must be capable of automatically distinguishing the types and operational characteristics of the detectors and other field devices. Should devices with different specifications be mistakenly installed in place of those removed for maintenance or similar reasons, the fire alarm panel must be able to display a warning message to the operator. The removal of any detector shall be indicated as a fault on the fire alarm panel.

A visible signal shall be provided on the body or connection socket of operational detectors. If detectors are concealed beneath raised flooring or behind ceiling voids, a visible signal shall be provided in the same manner as for standard visible installations.

Appropriate detectors shall be selected according to the location, environment and function for which they are intended.

Contamination of the detector head shall be visible on the Fire Alarm Panel.

Detectors shall have the following characteristics:

- Removable without affecting the system
- No circuit break upon removal
- Prevention of faults that could cause false alarms
- Transmission of pre-alarm and maintenance alarm signals

Beam detectors shall be configurable with a monitoring length between 5 metres and 100–150 metres. The monitoring width to the right and left shall be a maximum of 7.5 metres. It must be capable of being integrated into the loop via an addressing module. The external power supply to be used for the beam detector's power supply shall comply with the EN 54-4 standard (certificate shall be provided) and fault conditions shall be monitored via a relevant module. It shall comply with the characteristics and performance criteria specified in the EN 54-12 standard.

8.1.13.19. Detector Base

Detector bases shall be manufactured from white soft material and shall have terminals made of stainless steel.

In raised floor and suspended ceiling detector installations, the base shall be connected to a red indicator LED and its operational status shall be clearly visible from the outside.

All bases shall share common access points and connections to allow for the replacement of detectors.

Underneath the detector bases, a dust- and water-resistant enclosure with a minimum IP54 rating shall be used to protect the detector connection terminals from external factors such as earth leakage, dust and water.

8.1.13.20. Linear Heat Detection (LHD) System

In the areas beneath the platforms, LHD cables shall be installed along the MV and DC cable trays.

Linear Heat Detection (LHD) equipment shall be installed in the cable trays and/or ladders carrying MV cables, DC cables, and cables between the LV main distribution board and LV sub-distribution boards within the electrical shafts.

The LHD system technology to be used shall be capable of rapidly detecting temperature increases and shall be designed to operate reliably under the conditions of relative humidity, vibration, airflow velocity and temperature fluctuations expected in railway operations.

The linear fire detection system shall consist of the following components:

- Copper PVC analogue cable
- Indicator (control panel)
- EOL (End of Line) termination unit
- Power supply and battery set

The control panel and linear cable to be used shall be of the same brand.

In addition, both the display and the analogue LHD cable shall be EN 54-22 certified.

Fire pre-alarm, alarm and fault conditions can be monitored via station-addressed fire alarm panels using monitoring modules.

All analogue cables shall have 2 or 4-core copper conductors and shall be secured with cable brackets at intervals of no more than 0.5 m along their route.

The detector’s sensor cable shall not be affected by dust, humidity or ambient vibrations whilst active.

The pre-alarm and alarm temperature thresholds (54 °C – 105 °C) for the detector can be selected at different values.

If the temperature on the sensor cable exceeds the set value, an alarm shall be triggered on the alarm display (analyser = control panel).

If an open circuit or short circuit occurs on the detector’s sensor cable, the detector shall generate a fault signal.

The analyser shall feature alarm and pre-alarm relay outputs.

These alarms can be monitored via addressable modules from an addressable fire detection system.

All analogue cables shall be secured with cable clamps at intervals of no more than 1 metre along their route.

The detector shall have a reset input to allow for remote resetting.

The sensor cable can be used for up to 500 metres.

In addition, the linear temperature sensor cable shall have the following characteristics:

- The cable (LHD System) shall consist of two or four copper conductors, each with a colour-coded insulation made of a polymer with a low thermal expansion coefficient.
- The conductors shall be twisted and covered with a flame-retardant outer sheath reinforced with bronze-phosphorus.
- The type of analogue sensing cable to be used shall be determined during the design phase.
- The cable shall be PVC-sheathed.
- In addition, the threshold temperature value for the selected cable must also be determined in advance (e.g. 68 °C, 88 °C, etc.).

The analogue linear temperature detection control panel shall be supplied together with a 24 V DC power supply, a battery set, and a linear detection cable termination box, with a maximum cable capacity of 500 metres. One analogue linear detection IP66 termination box shall be used for each indicator panel.

8.1.13.21. Fibre-Optic Temperature Detection System

A fibre-optic temperature sensing system shall be used, covering the tunnels from the end of the platform. If requested by the Authority, a fibre-optic temperature sensing system may also be used for the stations.

The fibre-optic temperature detection system shall have the following features:

- The control units shall be 4-channel and shall be installed in the communications/electrical equipment room at each station.
- The capacity of each control unit shall be determined according to the tunnel length.

- Both the evaluation unit and the fibre sensing cable shall be VDS-approved in accordance with the EN 54-22 standard.
- The control unit shall analyse the signal values received from the sensor cable, compare them with pre-programmed alarm criteria, and generate an alarm signal if any of the criteria are met.
- The control unit shall have programmable relay contact outputs assigned to these signals to transmit alarms or system faults.
- The control unit shall feature digital inputs for alarm acknowledgement or reset.
- The control unit shall have an input/output port capable of communicating in accordance with international standards to enable communication with SCADA. (For example, MODBUS TCP-IP, MODBUS RS485, etc.)
- It shall have the sensitivity required to prevent false alarms caused by temperature fluctuations.
- It shall be possible to monitor for cable breaks in the linear fire detection cable.
- In the event of a break in the fibre-optic sensor cable at any point, the system shall continue to operate seamlessly and perform detection up to the point of the break without causing any technical or safety issues.
- The control unit at each station shall be installed with a backup provided by the control unit at the preceding or subsequent station.
- The fibre sensor cable **(**linear fire detection sensor cable) shall consist of two independent multimode 50 or 62.5/125 µm fibre strands. The cable outer sheath shall be LSZH (Low Smoke Zero Halogen). It must be installed in service galleries, cable shafts, under-platform areas and within tunnels using hot-dip galvanised cable suspension brackets. It shall be accompanied by an OTDR test report issued by the manufacturer, confirming that the sensor cable has been calibrated and tested with the fibre optic control unit.

8.1.13.22. Escalator, Moving Walkway and Lift Systems

The Station Fire Detection and Alarm System shall monitor the alarm statuses of the linear heat detection systems for each individual escalator and each individual moving walkway. The design shall take into account that the LHD cables for the escalators and moving walkways shall be supplied and installed by the escalator and moving walkway manufacturer.

Detection shall be carried out using LHD in the escalator shafts. Fire alarm information shall be fed into the Fire Detection and Alarm System via a contact from the escalator control panel.

An addressable optical smoke detector shall be installed on the ceiling of the lift shafts. The detectors shall be positioned in the most suitable locations in an accessible manner.

8.1.13.23. Installation

8.1.13.23.1. Cabling and Piping

Low-voltage cables shall be routed separately from power cables.

The loop cables for the Fire Detection and Alarm System shall be routed through the cable tray or along the ceiling (using halogen-free spiral conduits).

EMT conduits shall be used for surface-mounted installations on walls.

The lower end of the EMT conduit shall be terminated above the device, whilst the upper end shall be connected to a halogen-free spiral conduit within the suspended ceiling using special couplings.

If there is any wall cladding, the conduits shall be lowered and secured to the wall using halogen-free spiral conduit brackets in the void between the cladding and the wall.

In technical areas, wall runs shall be installed on the surface of the plaster using halogen-free rigid conduit or EMT conduit.

Tapered sleeves shall be used at all cable connection points.

Fire detection and alarm system cables shall be FE180 PH120.

8.1.13.23.2. Installation of Detectors

Detector mounting locations shall be at least 50 cm away from lighting fixtures and walls, and at least 50 cm away from supply and exhaust vents, in accordance with current standards.

Fire signal cables shall be routed to the installation site within halogen-free spiral conduits; where the detector is on the ceiling, this shall be done using cable clamps, and where it is under the floor, using a cable tray.

Halogen-free cable glands shall be installed at the detector mounting locations. Cables shall enter and exit through these glands.

A movable metal base shall be prepared for raised floor detectors. A halogen-free junction box shall be mounted on this base.

The detector base shall be mounted onto the box cover.

8.1.13.23.3. Installation of Input/Output Modules

Input/Output modules shall be placed inside an empty panel with IP54 protection. The internal design of the panel shall be specified in the system design documentation.

Under no circumstances shall the input/output modules be mounted on a ceiling or wall.

Cables shall be routed from the field equipment to the module panel via halogen-free (HF) spiral conduits or a low-voltage trunking system, secured with cable clips on the ceiling.

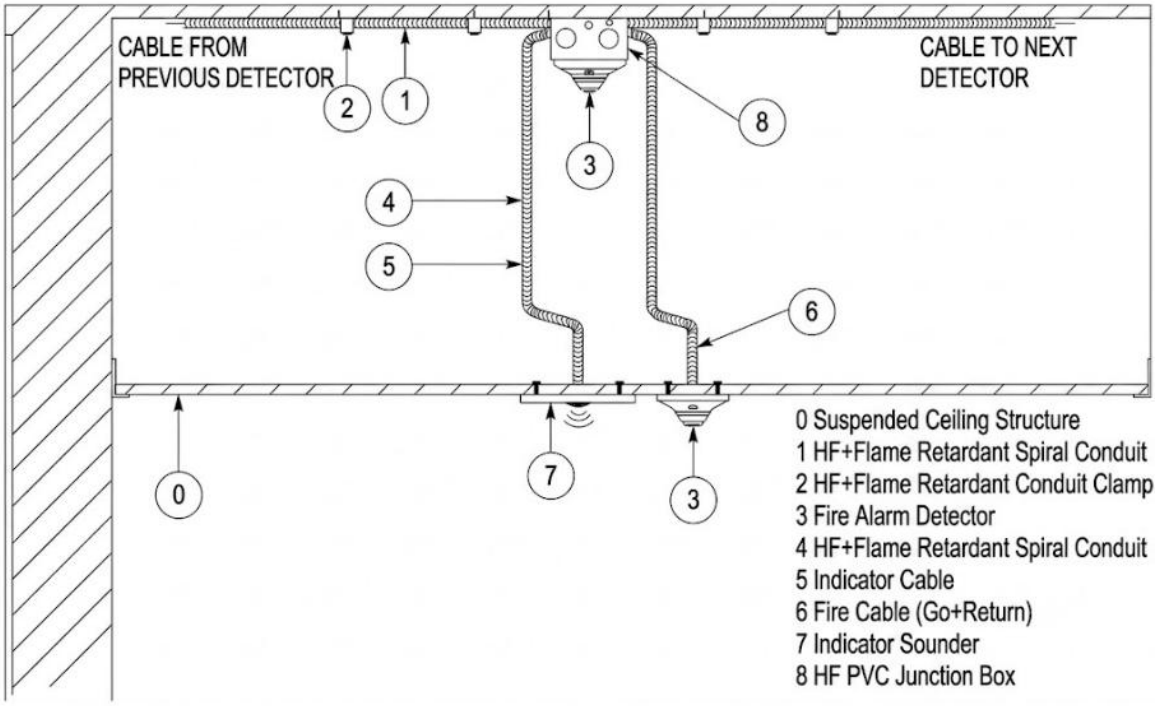


Figure 8.4 : Detailed Installation of Detectors in Areas with Suspended Ceilings

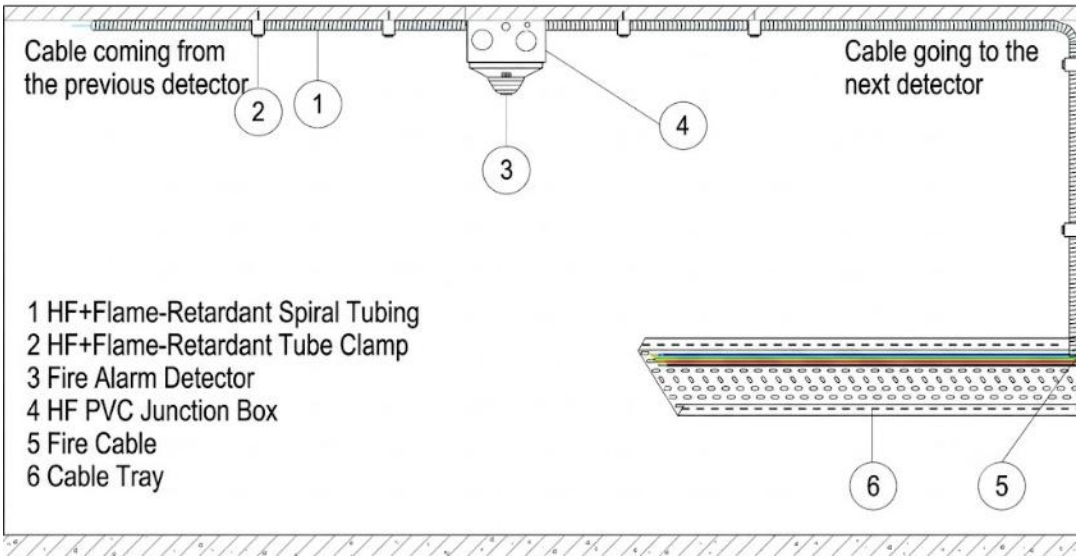


Figure 8.5 : Detailed View of Detector Installation in Areas Without a Suspended Ceiling

8.1.13.24. Interface with Other Systems

The system shall obtain time information from the Central Time System. Time information shall be kept constantly up to date.

There shall be an interface with the Public Address System to activate audible alarms in the event of an alarm. Upon the Fire Detection and Alarm System transmitting the alarm status to the SCADA System, the SCADA system shall broadcast a pre-recorded message via the public address system to alert station personnel.

Fire Detection and Alarm Systems shall be continuously monitored by the SCADA system.

The SCADA system shall provide control, monitoring and fault detection functions for all station fire detection and alarm system equipment. The SCADA Workstation shall form an integrated part of the fire detection and alarm system within the SCADA System and shall serve as the central point for collecting all station SCADA data, as well as a guidance tool for staff, covering fire alarms, evacuation procedures resulting from a fire, and the display of fire faults from the alarm system.

All fire alarms, faults and indications shall be transmitted via a redundant serial communication circuit between the Fire Alarm Panel and the SCADA System. Both path and source redundancy shall be provided in the connections between the Fire Alarm Panel and the SCADA System.

In addition to serial communication, status information regarding General Isolation, General Fault, Water-based Extinguishing System Active and Fire Alarm shall be transmitted to the SCADA system via dry contact relays on the panel. The ‘Fire Scenario Initiated’ signal from the SCADA system shall be transmitted to the fire alarm panel via a digital input.

8.1.13.25. Software and Licensing

Graphical monitoring software shall be used to visually display, archive, document and control connected peripheral devices based on messages received from the fire detection and alarm system.

Regardless of location, one or more control panels situated in different locations can be monitored via either the Internet (WAN) or an Intranet (LAN).

A proprietary communication protocol from the manufacturer shall be used between the control panel and the graphical monitoring software. A connection between the software and the control panel can be established via TCP/IP or RS-232/422/485.

All event logs generated by the system shall be retained in event log files for a minimum of three months, along with date and time information. These logs can be exported in file formats such as xls, csv, etc., upon request.

The software shall allow the creation of users with different levels of authorisation. All configurations may only be carried out by authorised users.

The software shall include a feature for creating and viewing graphical maps.

The graphical map shall be designed to clearly display all areas monitored by the system—such as platforms, concourse levels, and entrances/exits—alongside a general map showing the entire station/centre.

Maps shall be created using 2D graphics rendered with perspective using appropriate software.

The equipment codes, locations and status information (active, faulty, etc.) of all panels and connected equipment shall be displayed and monitored in real time.

All detectors, call points, and entry/exit devices (IOM) shall have their own unique address numbers assigned to specific fire zones.

In the event of a fault in any equipment within the system (detectors, call points, input and output devices (IOM), communication faults, etc.), a visual and/or audible alarm shall be triggered on both the local and central operator screens.

Faults shall be classified by type and recorded in the event logs along with the equipment name, date and time.

The software shall be capable of fulfilling many of the system's requirements, such as adding equipment, defining zones, and retrieving event logs.

Hardware (detectors, buttons, IOMs, etc.) and software (zones, etc.) additions can be made to the system at a later date, and monitoring sessions can be added at any location. Should a licence be required for these additions, a number of spare session licences equivalent to 20% more than the total number of sessions shall be provided.

The integration software shall be provided by the manufacturer.

The software shall have a Turkish and English user interface. If Turkish language support is not available, language files shall be obtained from the manufacturer and translated to ensure the user interface is displayed in Turkish. Additionally, the software shall perform the following functions:

- Taking the group out of service, bringing it back into service, putting it into revision mode, putting it into silent revision mode,
- Taking circuit elements out of service, bringing them back into service, putting them into revision mode, silent revision mode, and resetting
- Silencing, taking sirens out of service, bringing them back into service, and resetting them,
- Generating alarm and fault simulations,
- Battery monitoring,
- Resetting contamination,
- Management of confirmation and control processes,
- Monitoring of alarm, fault, error, out of service, in service, siren activation, siren deactivated, siren faulty, communication with the fire brigade, communication with the control panel, and activation of the verification and control process.

8.1.14. Cables

8.1.14.1. General

The specifications provided under the heading for each system shall apply to the cables to be used in control and communication systems. Furthermore, all cables to be used in control and communication systems shall also possess the characteristics specified in this section.

All cable sheaths to be used in control and communication systems shall be rodent-resistant, containing anti-rodent additives that render them unpalatable to rodents and prevent damage.

All cables for control and communication systems shall be of the low-smoke zero-halogen (LSZH - LSHF) type, flame-retardant, and of a quality suitable for the requirements of the railway line.

All cables within the tunnel (excluding leaky transmission cables belonging to the digital radio communication system) shall be fire-resistant (FE180 PH120) and armoured.

At the points where cables from different systems intersect, EMC conditions shall be adhered to, measures shall be taken to prevent electromagnetic interference, and all relevant system cables shall be of a shielded type to prevent electromagnetic interference.

All cables within the tunnel shall be routed through physically separated channels to ensure the continuity of communication services in the event of exceptional circumstances (e.g. derailment of a train).

The types of cable to be used in control and communication systems shall be as set out in the table below, without limitation:

Table 8.13 : Types of Cable to be Used in Control and Communication Systems

From	**To**	**Cable Type**	**Rating**
Station (Transmission)	Station (Transmission)	Fibre Optic (Armoured)	FE180/PH120
Transmission Cabinet	Public Address System Cabinet	CAT-6	S/FTP
Transmission Cabinet	Access Control Cabinet	CAT-6	S/FTP
Transmission Cabinet	Telephone Exchange / Cabinet	CAT-6	S/FTP
Transmission Cabinet	Passenger Information System Cabinet	CAT-6	S/FTP
Transmission Cabinet	Radio Cabinet	CAT-6	S/FTP
Transmission Cabinet	Clock Cabinet	CAT-6	S/FTP
Transmission Cabinet	Billing Cabinet	CAT-6	S/FTP
Public Address System Cabinet	Loudspeaker	LIHCH	FE180/PH120

From	To	Cable Type	Rating
Public Address System Cabinet	Noise Microphone	LIHCH	FE180/PH120
CCTV Workstation	CCTV Main PoE Switch	CAT-6	S/FTP
CCTV Main PoE Switch	PoE Switch	CAT-6	S/FTP
PoE Switch	Camera	CAT-6 (PoE)	S/FTP
Data Switch	Data Socket	CAT-6	S/FTP
Telephone Patch Panel	Telecom Service Provider Line	CAT-3 or HBAPH	
Telephone Patch Panel	Telephone	CAT-3 or HBAPH	
Telephone Patch Panel	Tunnel Telephones	CAT-3 or HBAPH	FE180/PH120 (for HBAPH)
Telephone Patch Panel	Emergency Telephones	CAT-3 or HBAPH	FE180/PH120 (for HBAPH)
Fee Collection Cabinet	Turnstiles	CAT-6	S/FTP
Passenger Information System Cabinet	Passenger Information Display	CAT-6	S/FTP
Clock Cabinet	Digital Clock	CAT-6	S/FTP
Radio Cabinet	Along the Tunnel	Leaky - Leaky/Split Cable	
Radio Cabinet	Radio Equipment (Coupler, Splitter, Antenna)	Coaxial Cable	
Fire Alarm Panel	Fire Detection Equipment	JE-H(st)H	FE180/PH120
Fire Alarm Panel	Remote Fire Alarm Panel	JE-H(st)H	FE180/PH120
SCADA Workstation	SCADA RTU Cabinets	CAT-6 or Fibre Optic	S/FTP
SCADA RTU Cabinets	SCADA RIO Cabinets	LIHCH	FE180/PH120
SCADA RIO Cabinets	Equipment/System Cabinets	LIHCH	FE180/PH120

8.1.14.2. Standards

All data transmission and signal cables to be used in the system

- must be compliant with standards,
- high-quality conductors compliant with the latest standards,
- with insulation and outer sheaths compliant with HFFR (halogen-free, flame-retardant)
- compliant with TS EN 50290 standards,
- flame spread/flame retardancy compliant with IEC/EN 60332-1,
- smoke density compliant with IEC/EN 61034-2/EN 50268,
- Gas density measurement (acid gas emissions) in accordance with IEC/EN 60754-1/2 and EN 50267
- The primary screen must be 100% opaque, whilst the mesh screen must be at least 65% opaque, depending on its type,

shall be.

The colour schemes for all cables shall be determined in accordance with standards and during the design phase.

Where CAT-6 cable is used, fibre optic cable shall be used if the cable length exceeds 90 metres.

In addition to the above, all cables to be used in emergency situations and emergency scenarios

- FE180 PH120, which maintains conductivity with the same performance for three hours under fire and an additional 120 minutes under impact, halogen-free, shielded, with continuous insulation
- maintain functionality under fire (BS 6387 C/W/Z, IEC 60331, TS EN 50200, TS EN IEC 60331-1, BS 6387 W/Z 2 and other relevant standards),
- Compliant with standards regarding toxic and flammable gases (IEC 60754-1-2, EN 50267, BS 6425-2 and other relevant standards),
- Equipped with a flame barrier to prevent flame spread and compliant with standards (IEC 60332-1-3, EN 50266 and other relevant standards),
- Low smoke density (BS/IEC/EN 61034-1/2, BS 7622 and other relevant standards),
- With a screen coverage of at least 65% for the second outer braided screen type,
- Flame-retardant (TS EN 60332-1-3-24, BS 4066 and other relevant standards)

and shall be designed in accordance with the most current applicable standards.

Cables for the public address system shall, in addition to the above, be selected to be highly flexible, noise-free, shielded, and having the lowest attenuation values within the specified references.

In addition to the criteria described above for fibre optic cables,

- Attenuation Measurement,
- Crush Resistance Performance,
- Impact Resistance Performance,
- Tensile Strength Performance,
- Water Tightness Test,
- Temperature Cycling Performance,

shall be assessed, and these cables shall comply with TS EN IEC 60793, TS EN IEC 60794, TS EN 50173 and other relevant standards.

In general, fibre optic cables shall be selected in accordance with the relevant standards to be resistant to mechanical stress, temperature, humidity, water and chemicals, unpalatable to rodents, repellent to pests, and UV-resistant.

8.1.14.3. Cable Laying and Termination

Products from manufacturers meeting the necessary quality standards for all types of cable termination equipment shall be used. Terminations shall be carried out in accordance with the manufacturers' instructions.

The design shall take into account that all cables to be used shall be run in one continuous length from one point to another without any splices; however, a splice may be made if the length of a specific cable run exceeds the maximum length for which the cable can be manufactured.

Fibre optic cabling and terminations shall be carried out in accordance with the TS EN IEC 61754 and ANSI/TIA/EIA-568-C.3 standards.

The switching, routing and termination equipment of the transmission system shall be installed in telecommunications rooms and housed in cabinets compliant with the IEC 60297-3 standard.

8.1.15. Installation Conditions

Suspension brackets, consoles, rods and tension wires shall be selected from stainless steel material.

All cable supports, duct systems, equipment, etc. shall be properly earthed.

Duct groups, cable hangers, supports, etc. shall be dimensioned to allow access to the ducts for maintenance, and sufficient spacing shall be maintained between cables belonging to different functional circuits.

The installation of communication and control systems shall be carried out in full coordination with the construction, structural, finishing (architectural), mechanical and electrical systems; in particular, requirements for embedded ducts, underfloor duct systems, etc. shall be coordinated.

All installation work shall be carried out in accordance with the manufacturers' instructions and relevant standards.

Unless otherwise specified, cable entries/exits to all panels and cabinets for communication and control systems shall be made from below using an appropriate number and size of cable glands; in panels with dense cable entries where the use of cable glands is not feasible, flexible, dust-tight, halogen-free material (such as sealing tape) shall be used. Brush-type materials shall not be used at the cable entries of panels and cabinets.

In tunnels, viaducts and all open areas, cable protection fittings—including their components—for connecting all cables belonging to communication and control systems from the cable ducts to the equipment shall be selected from stainless steel (Grade 316) piping materials.

8.1.16. Rack Cabinets

Cabinets to be located in indoor environments such as communication rooms for control and communication systems shall have a minimum IP54 protection rating; rack cabinets to be located in outdoor environments shall have a minimum IP65 protection rating.

The technical specifications of the rack cabinets shall be determined according to applicable AYGM/Administration requirements, IEC 60297/60917 series, environmental conditions and the equipment loading requirements of the INRAIL Line.

8.1.17. Software and Licences

Software and licences shall be required for the operation, configuration, maintenance and fault diagnosis of all systems.

Licences shall have no time limit. Software and licence redundancies specified under the relevant system heading shall be provided. Where not specified under the relevant system heading, and where licensing is based on the number of users or equipment, the design shall take into account that licences sufficient for at least a 20% expansion of the installed system shall be provided free of charge.

9. MECHANICAL SYSTEMS

9.1. SCOPE OF DESIGN

This section has been prepared to guide mechanical installation design work in station and line structures (specifically for tunnels, etc.) from a holistic perspective, taking into account the complexity of designing station and line structures where requirements such as life safety and comfort intersect. It also covers general aspects relating to emergency and fire safety systems.

Mechanical engineering design encompasses the planning of the following systems:

- VENTILATION
  - TUNNEL VENTILATION
  - STATION VENTILATION
    - ✓ GENERAL AREA VENTILATION
      - Platforms,
      - Ticket Hall (Controlled and Uncontrolled Areas),
      - Commercial Floors
      - Passenger Corridors, Connecting Tunnels
      - Lifts,
      - Escalators.
    - ✓ SPECIAL AREAS VENTILATION
      - OG-DC(-AG) equipment room, Transformer room,
      - Battery rooms,
      - Escalator control rooms,
      - Communications room,
      - Signalling room,
      - Fibre optic room,
      - GSM rooms,
      - Electronic equipment rooms,
      - Fan rooms,
      - Fire pump rooms,
      - Wet areas (toilets, staff changing rooms, cleaning rooms, baby care rooms),
      - Drainage and sewage pump rooms,
      - All areas occupied by staff (Control Room, Staff Room, Medical Room, Mosque, Ablution Room, etc.),
      - DC Isolation Room,
      - Standby Rooms.
- HEATING AND COOLING
  - Heating and Cooling Combined;
    - Areas occupied by staff (Control Room, Staff Rooms, Medical Room, Prayer Room, etc.),
    - Technical areas (Communications, Signalling, Battery, Fibre Optic, etc. rooms).

- Heating Only;
  - Wet Areas (Staff Changing Room, Office (Commercial WC Staff Room), Baby Care Room).
  - Passenger toilets and staff toilets shall be heated if they are located above ground.

- FIRE PROTECTION SYSTEMS
  - Automatic Sprinkler,
  - Fixed Pipe System and Fire Cabinet System,
  - Hydrant Systems,
  - Automatic Gaseous Extinguishing Systems.

- PLUMBING
  - Potable cold and hot water system,
  - Wastewater system,
  - Drainage system.

In the selection and design of mechanical systems, national and international standards in force at the time of design shall be taken into account.

The list of standards is provided in the relevant section.

9.2. DESIGN APPROACH

Mechanical installations shall be designed taking into account the local conditions of the stations and their relationships/connections with other structures in the vicinity.

All equipment serving the station buildings shall be selected from the high-efficiency class, thereby aiming to reduce total carbon emissions.

The feasibility of applying a heat recovery ventilation strategy for the ventilation of station ancillary areas, and in particular office-type spaces, shall be assessed on a station-by-station basis. Variable speed drive technology and building automation shall be utilised optimally to reduce system motor loads. By establishing an integrated automation system, the system shall be guaranteed to operate throughout its entire service life whilst minimising energy loss, utilising various techniques such as proportional control, deactivation of non-operational equipment, programming of optimal operating times, remote control, and outdoor air compensation.

9.3. VENTILATION SYSTEM

The aim of this section is to outline the fundamental principles of tunnel and station ventilation system design and to establish a foundation for the design of a modern tunnel and station

ventilation system capable of simultaneously addressing various parameters such as comfort, operational efficiency and safety.

9.3.1. References, Standards, Regulations and Publications

The current publication dates of the references listed below shall be taken into account.

TS Standards

- TS 825 – Thermal Insulation Rules for Buildings
- TS 2164 – Rules for the Design of Heating Systems

TS EN Standards

- TS EN 12101 – Smoke and Heat Control Systems
- TS EN 12101-6 – Smoke and Heat Detection and Alarm Systems – Part 6: Technical Specifications for Differential Pressure Systems – Kits
- TS EN 50272-2 – Safety Requirements – Secondary Batteries and Installations – Part 2: Stationary Batteries

EN Standards

- EN 2008/163/EC – Safety Directive for Rail Systems
- European Union Directives
- Safety in Railway Tunnels Technical Specifications for Interoperability (TSI)

BS Standards

- BS 7346 – 7 Components for Smoke and Heat Control Systems - Part 7: Code of Practice on Functional Recommendations and Calculation Methods for Smoke and Heat Control Systems for Covered Car Parks

NFPA Standards

- NFPA 92 – Standard for Smoke Control Systems
- NFPA 130 - Standard for Fixed Guideway Transit and Passenger Rail Systems
- NFPA 204 – Standard for Smoke and Heat Venting

ASHRAE Standards

- ASHRAE 15 – Safety Standard for Refrigeration Systems
- ASHRAE 55 – Thermal Environmental Conditions for Human Occupancy
- ASHRAE 62.1 – Ventilation for Acceptable Indoor Air Quality

- ASHRAE – Handbook of HVAC Applications Chapter 15 – Enclosed Vehicular Facilities
- ASHRAE Handbook: Fundamentals

Other International Standards/Guidelines

- International Mechanical Code
- US Department of Transportation, Subway Environmental Design Handbook

Regulations

- Regulations on the Fire Protection of Buildings (BYKHY)
- Building Energy Performance Regulation
- Regulation on the Assessment and Management of Environmental Noise
- General Directorate of Infrastructure Investments, Design Technical Specifications

Other Publications

- Institution of Mechanical Engineers (MMO), Air Conditioning Systems
- Subway Environmental Design Handbook

9.3.2. Tunnel Ventilation

This section explains the fundamental principles of the Tunnel Ventilation System (TVS) and the analysis activities required to guide its architectural and structural design, whilst also defining the design parameters commonly used for TVS system design.

The Tunnel Ventilation System shall be used to control environmental conditions in tunnels and stations under normal, congested and emergency conditions. This is primarily an emergency ventilation system that creates an acceptable escape route for passengers to exit the tunnel and station in the event of a fire or emergency likely to occur in the tunnel or stations. During normal, congested or maintenance operations in the tunnels. The TVS shall be capable of operating in natural ventilation mode (all fans off, piston relief shafts open) or shall have the capacity and capability to maintain acceptable temperatures and air quality whilst ensuring critical airflow rates. No air-conditioning-based cooling system shall be installed in stations or tunnels. Consequently, the THS shall act as the primary mechanism for regulating ambient temperature in the tunnels through natural ventilation.

9.3.2.1. Design Criteria

The design criteria to be used in the tunnel ventilation system are summarised in the table below.

Table 9.1 : Air temperatures

Ambient	
Station – Indoor Conditions	
Summer: Dry-bulb thermometer Design Time	Outdoor Environment + 5°C 5.00 pm, weekdays
Station Maximum Temperature	40 °C
Tunnel – Normal Operation	
Preferred Maximum Temperature	Ambient Temperature + 5°C
Maximum Average Temperature	40°C
Tunnel – Crowded Operation	
Recommended Maximum Temperature	Ambient + 5°C
Maximum average temperature*	40 °C
Maximum Temperature for Electrical Equipment	40 °C

* Should the maximum average temperature specified in this section not be achievable with the systems described herein, alternative solutions must be submitted for approval by the Authority.

Air velocity design criteria are provided in the table below.

Table 9.2 : Air velocities

Station Common Areas	
Maximum air velocity:	
Platform, Ticket Hall, Horizontal Access Routes	5 m/s
Stairways	2,5 m/s
Average air velocity:	
Platform, Ticket Hall, Horizontal Access Routes	3 m/s
Ventilation shaft	
Nominal air velocity:	9 m/s
Maximum air velocity:	11 m/s
Ventilation Equipment	
Silencer inlet velocity:	
Nominal air velocity	5 m/s
Maximum air velocity	6 m/s
Damper inlet velocity:	
Nominal air velocity	7,5 m/s
Maximum air velocity	10 m/s
Grille and louvre:	
Maximum air velocity	2,5 m/s

In cases where the design criteria provided in the tables above cannot be met or these values cannot be adhered to, the station and tunnel architectural design shall be verified by conducting simulations and the necessary engineering analyses, applying the train characteristics exactly as specified, to confirm the suitability of the accepted value and the analysis performed using this value. This analysis shall also examine the evacuation routes for passengers. The internal noise levels to which passengers or staff shall be exposed must comply with the criteria established by occupational health and safety authorities for hearing protection and preservation. Hearing damage can potentially occur in the long term when the time-averaged noise level exceeds 85 dBA. For this reason, noise levels shall be kept below 85 dBA throughout the station, including the tunnel ventilation plant room.

When the Tunnel Ventilation System fans are not operating during normal train operations, there shall be no noise. In this mode, the piston effect dampers are normally open, and the tunnels and stations naturally exchange air and heat with the environment via the piston effect caused by the train. The street-level ventilation hatches shall be large enough to prevent the air velocity generated by the piston effect from creating noise.

During emergency operations, the maximum noise level of the fans should be 115 dBA for a few seconds and 85 dBA, which is lower than the level specified in NFPA 130. The fans' silencers and sizing must be selected by the fan manufacturer in accordance with these requirements during the implementation phase.

9.3.2.2. System Description

The tunnel ventilation system shall be designed to mitigate the adverse effects of airflow and thermal loads generated by train movements.

Two main tunnel ventilation fans shall be installed in each station fan room or in the fan room of each ventilation shaft structure constructed for long tunnel sections without stations. The fans shall be sized such that, in the event of the failure of one fan, the remaining fan is capable of providing at least 100% of the required tunnel ventilation capacity. Where necessary to achieve the required ventilation performance, a jet fan system may be provided to supplement the main tunnel ventilation fans. The mechanical equipment in each tunnel ventilation shaft shall consist of fans, inlet and outlet dampers, louvers and silencers. The fans shall have fully reversible axial flow capable of operating in both supply and exhaust modes. A piston relief damper shall be installed in each piston relief shaft. During normal operation, the piston relief damper shall be open; however, should the fans be activated in the tunnel during a potential emergency, the piston relief dampers shall close. Fan dampers shall be installed on the inlet side of the fan and shall open when the fans are activated.

To ensure fan operation and damper positions are appropriate for each operational condition, the tunnel ventilation equipment shall be controllable both locally (from the Station Control Room)

and remotely from the Control Centre. The status of the fan and the damper position shall be indicated via signals sent back to the Control Centre.

9.3.2.3. Tunnel Ventilation System Design Assumptions

In emergency situations, the airflow within the tunnel cross-section shall be calculated based on a blockage caused by a maximum of two trains stopping between two ventilation facilities. The number of trains in emergency scenarios shall be determined according to the results of the operational simulation. The capacity of the ventilation system shall be selected to ensure critical airflow even if one fan is not operational in the event of a train fire.

The following parameters shall be taken into account in the simulation studies.

The design fire heat release rates for passenger and freight train scenarios shall be determined through a project-specific fire engineering assessment. As an initial design basis, passenger train fire scenarios shall generally be assessed within the range of 20–40 MW, while freight train fire scenarios shall be assessed within the range of 30–50 MW for non-dangerous goods traffic and higher values for dangerous goods or high fire-load cargo, where applicable. When determining the heat release ratio for design purposes, manufacturer data and relevant EN directives will be taken into account.

The fire growth rate for passenger train design fire scenarios may initially be taken as medium t-squared growth, unless a more onerous growth rate is required by the project-specific fire engineering assessment, tunnel ventilation analysis, rolling stock characteristics or applicable standards.

For freight train fire scenarios, the fire growth rate shall be determined on the basis of the transported freight type, fire load, cargo configuration, tunnel ventilation conditions and risk assessment. Medium t-squared growth may only be adopted where it is justified for the applicable freight scenario and accepted by the Engineer. For high fire-load, combustible, intermodal, tanker or dangerous goods scenarios, fast or more onerous fire growth rates shall be assessed.

The final design fire values shall be justified by the Contractor and accepted by the Engineer.

A summary of the main assumptions made for the Environmental Control Simulation is as follows:

- Maximum number of trains in a ventilation zone: to be determined based on the outcome of the operational scenario.
- Fans must operate at full capacity and efficiency in both directions.
- In the event of a fire, 80% heat transfer by convection and 20% heat transfer by radiation shall be taken into account.

- Smoke heat transfer coefficient for a train fire = 0.2 (the use of a smoke heat transfer value of 0.1 shall be evaluated in future studies).
- Pedestrian cross-passages in the tunnel are assumed to be closed during normal operations. In emergency scenarios, at least one pedestrian cross-passage is assumed to be open, depending on the location of the fire.
- It is assumed that TVS maintenance shall be carried out outside operating hours.
- All data that cannot be provided during the design phase shall be estimated based on general practice and experience from other projects.

9.3.2.4. Scope of Work

The tunnel ventilation system shall ensure the control of underground environmental conditions under the following operational conditions.

9.3.2.5. Normal Operation

Air movements caused by the train piston effect and thermal loads from trains affect passenger areas at stations. Under normal conditions, where train operations adhere to the scheduled programme, temperature and air velocity control shall be maintained within the tunnel.

If temperatures in the tunnels rise excessively in hot weather, tunnel ventilation fans shall be activated to draw in fresh air from outside and exhaust hot air, thereby supplementing the air exchange created by the train piston effect.

9.3.2.5.1 Congested Operations

Should trains come to a halt for a pre-planned or unplanned period, the tunnel ventilation fans shall be activated to maintain the airflow normally achieved through the train piston effect.

Should temperatures in the station tunnel reach critical levels due to thermal loads, the tunnel ventilation fans shall operate in ‘exhaust’ mode; the resulting negative pressure, combined with the fresh air supply fans at the station, shall ensure the necessary airflow. In the event that temperatures in the tunnels between stations reach critical levels, one station shall operate in “exhaust” mode and the other in “supply” mode to create the necessary airflow. This operating mode can be initiated automatically when it is detected, either manually or via the signalling system, that no train has passed for an extended period.

9.3.2.5.2 Exceptional Conditions

An exceptional condition is defined as a fire occurring underground, including a train or tunnel fire, without imposing any restrictions. This definition pertains to the tunnel ventilation system’s response to exceptional conditions. The tunnel ventilation system shall supply fresh (outdoor) air

to the fire area to reduce the effects of combustion products (smoke), remove the products (sweep away the smoke) and lower the air temperature. Furthermore, the tunnel ventilation system shall control air flows within the tunnels to ensure the safe evacuation of passengers and operational staff during a fire and to facilitate the approach of emergency response personnel to the fire.

Depending on the location and size of the fire, the fans can be operated in various modes. Where overnight lines are established along the route, risk analyses shall be carried out for these lines, and the necessity for fans shall be determined based on the results.

In a tunnel, during a train fire, the tunnel ventilation fans shall operate in 'supply-exhaust' mode to ensure smoke extraction and safety. If necessary to ensure smoke extraction, fans at adjacent stations may also be activated.

The minimum air velocity required to prevent the accumulation of smoke and to force hot smoke to flow in the desired direction (smoke sweeping) is referred to as the "critical velocity". The Contractor shall calculate this critical velocity, and the outlet and inlet values of the tunnel ventilation fans shall include the value required to achieve the critical velocity in the tunnel or station tunnel (taking into account pressure loss, flow rate and maximum velocities). If the TVF fans at both ends of the station in the tunnel cannot provide these values, additional methods, including the opening of an intermediate shaft, must be considered. The ventilation velocity and temperature, pressure and velocity distributions required for the critical velocity shall be analysed using a computer-aided programme deemed suitable and approved by the Authority. The critical velocity formula contained in the Subway Environmental Design Handbook or empirically validated critical velocity formulas shall be used. If the critical velocity formula from the Subway Environmental Design Handbook is to be used, the K values shall be calculated based on the dimensions, shape, roughness, and other characteristics of the ventilation shaft in the design, to be demonstrated through fluid mechanics calculations.

In addition, computational fluid dynamics (CFD) analysis shall be carried out to visualise smoke dispersion in stations and track-switch areas. It shall be demonstrated that, in the event of a potential emergency scenario at stations, suitable environmental conditions are provided for passenger safety and rescue personnel.

9.3.2.6. System Configuration

The main components of the tunnel ventilation system shall be as follows:

- Air intake shafts at both ends of the stations shall help to counteract the train piston effect; the cross-sectional area of these shafts may vary depending on the capacity of the fans, which shall be determined as a result of the tunnel ventilation analysis. A maximum air velocity criterion of 11 m/s within the shaft shall be ensured in accordance with fan capacities. Each air shaft shall have a clear cross-sectional area of approximately 20 m². Such shafts should provide as unobstructed an air passage as possible.

- Two reversible fans, along with dampers connected to them, shall be installed on each side of the station. The fans shall have equal performance in both supply and exhaust modes.
- Piston relief dampers shall be positioned to ensure airflow between the railway and the surface during normal operations.
- Tunnel ventilation dampers shall be positioned so as to completely prevent air flow between the tunnels in the event of an emergency.
- Tunnel temperature sensors shall be installed at both ends of the stations and in the ventilation shafts to monitor the air temperature within the tunnel. As the sensors are intended to measure the average tunnel temperature, positioning them approximately 20 metres from the station–tunnel connection points shall be sufficient to ensure accurate measurement of the tunnel temperature. Should the average tunnel air temperature exceed the design temperature, the tunnel ventilation fans at the stations shall operate to cool the tunnel to the design temperature.

In the event of a tunnel fire, fan operation may vary depending on the location of the fire. Fans located further from the fire zone may be operated to assist in creating positive or negative pressure relative to fans closer to the fire zone and may not be directly involved in smoke extraction. This allows for increased airflow into the tunnel where the fire has broken out, thereby reducing the capacity of each fan at nearby stations. Assuming the power supply can simultaneously power all fans operating at the same time, this strategy can result in a reduction in the capacity of fans, shafts and all related equipment along the line, thereby achieving savings. This strategy can be adopted along the entire line and form the basis of the Tunnel Ventilation System design.

An example of the basic operating principle to be applied to the tunnel ventilation system is shown schematically in Figure 9.1. The station letters shown in the figure refer to either stations or ventilation shafts.

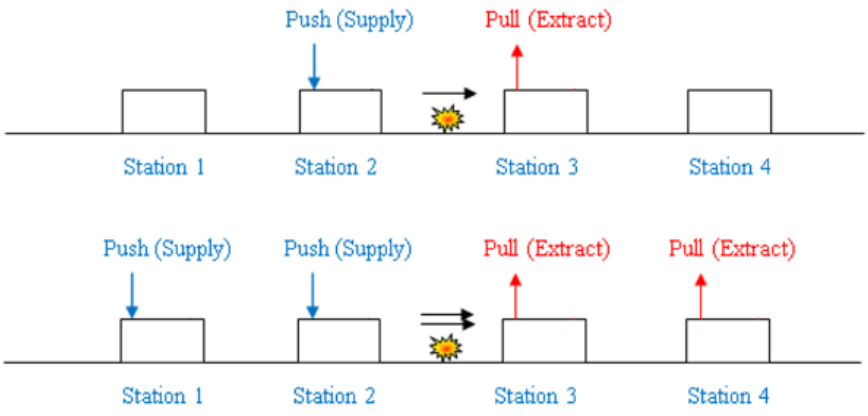


Figure 9.1 : Operating principle of the tunnel ventilation system.

9.3.2.7. Computer Simulation Tools

One-dimensional aerodynamic and thermodynamic modelling shall be carried out for the entire tunnel network under normal, congested and exceptional operating conditions using the Environmental Control Simulation (SES) or equal software.

The primary objective of the tunnel ventilation system modelling is to determine the capacities of ventilation system equipment in tunnels and stations and to establish the operating principle of the ventilation system. Based on the simulation results, the designer shall provide guidance on shaft locations and sizes, as well as the suitability of equipment capacities. Furthermore, based on the tunnel ventilation system analyses, boundary conditions shall be established for computational fluid dynamics simulations of emergency scenarios at stations deemed necessary.

The SES modelling carried out for this design phase does not include all the scenarios required to complete the detailed design of the system, nor does it include approval from the relevant authorities. The aim is to define the tunnel and station emergency ventilation systems with sufficient detail to approve the spatial and interface requirements. Advanced, extended SES analyses shall be carried out during the construction phase of the project to produce the detailed design and obtain approval from the relevant authorities.

Detailed Computational Fluid Dynamics (CFD) modelling must evaluate and ensure the implementation of heat and smoke movement within a given station for multiple fire scenarios.

9.3.3. Station Ventilation

As the design of the ventilation system directly affects the station's geometry and layout, it is essential that the design is carried out in accordance with the principles set out.

The station ventilation and air-conditioning system shall be designed to serve the purposes outlined below, in conjunction with the tunnel ventilation system.

- Heat dissipation throughout the station,
- Ensuring comfort within the station,
- Supply of fresh air throughout the station,
- Control of air movements caused by the piston effect,
- Ensuring smoke control in the event of a fire.

9.3.3.1. Design Criteria

In the design of the station ventilation system and the sizing of air ducts, the velocity values provided in Table 9.3 shall be used as a basis. Where these limit velocity values are partially exceeded due to architectural or structural constraints, necessary measures shall be taken in accordance with general acoustic design principles.

Table 9.3 : Ventilation velocities

Mechanical Ventilation System	
Ducts	**Maximum velocity (m/s)**
Fan rooms, building shafts, main ducts in shafts	11
Main ducts	8
Secondary ducts	4
Ventilation Equipment	
Equipment	**Maximum speed (m/s)**
Silencers	5
Louvers	4
Diffusers, vents, etc.	3
Pavement grates	5
Stations and tunnels	
Location	**Maximum speed (m/s)**
Platform, ticket hall, mezzanine	5
Stairs and escalators	2.5

As stations are underground structures, the design of air intake and exhaust points, ensuring appropriate air velocities, the relative positioning of these grilles, and their selection in accordance with environmental noise constraints are of paramount importance. The following key parameters shall be considered in the design of air intake and exhaust points;

- All grilles and pavement grates shall be selected in accordance with acoustic performance criteria, ensuring that the air velocities specified above are not exceeded.
- When determining fresh air intake and smoke exhaust points on the site plan, they shall be planned with a minimum distance of 5 m between them. Smoke exhaust points must be at least 5 m away from the exit points of emergency escape staircases. This distance shall be applied as a minimum of 3 m for exhaust outlets that do not discharge smoke. If there is a requirement to locate any fresh air intake grille in close proximity to a specific pollutant source, the distances to such sources shall be assessed separately according to the type of pollutant source.
- All grilles shall be selected to be Class A or at least Class B in accordance with the TS EN 13030 standard to reduce rain penetration. Class A grilles prevent rain penetration with 99% efficiency, whilst Class B grilles do so with a minimum of 95% efficiency.
- Should the acoustic measures taken in the installation prove insufficient, acoustic-type louvres shall be selected, ensuring that the pressure loss through the louvres does not exceed 50 Pa.

- Air discharge points shall be planned as far away from pedestrian traffic as possible, ensuring that air is not blown directly onto pedestrians. Should such a requirement arise, the air velocities specified in the table shall be used as a basis.

Table 9.4 : Design criteria for station ventilation systems

Room Name	Room Temperature		Relative Humidity	Fresh Air Volume		Direct Exhaust			Air Change Number	Occupancy	Lighting Load	Electrical Load	Noise Level	Room Pressure
	Winter (°C)	Summer (°C)	(%)	(m^3/h per person)	(m^3/h·m^2)	(m^3/h per person)	(m^3/h per unit)	(m^3/h·m^2)	(l/h)	(m^2/person)	(W/m^2)	(W/m^2)	(NR)	
Platform	-	38	-	-	-	26	-	-	(1)	1.5	20	-	45 / 70	Negative/Positive
Ticket hall, Passenger corridor	-	40	-		-	26	-	-	(1)	2	15	-	45 / 70	Negative
Tunnel (Normal/Congested Operation)	-	33 / 40	-		-		-	-	(2)	-		-	-	Negative
Baby Care	25	-	-	-	(4)	26	-	-	-	(3)	-	-	45	Negative
Toilet	-	-	-	-	(4)	-	150	-	-	-	-	-	45	Negative
Mosque	20	24	50	10	-	10	-	-	-	0.83	12	-	40	Positive
Washroom	-	-	-	-	(4)	-	150 (8)	-	-	-	-	-	45	Negative
Storage	-	-	-	-	2.2	-	-	2.2	-	-	-	-	-	Neutral
Fire pump room, Fan room, Spare room	-	-	-	-	-	-	-	-	4	-	-	-	-	Negative
Station control, Staff, Health	20	24	50	36	-	36	-	-	-	(3)	12	-	40	Positive
Meeting room	20	24	50	12	-	12	-	-	-	2.5	12	5	35	Positive
Service corridor	-	-	-	-	2.2	-	-	2.2	-	-	-	-	45	Positive/ Negative
Changing room	20	-	-	-	(4)	-	-	18	-	-	-	-	45	Negative
Drainage pump room, Sewage pump room	-	-	-	-	(4)	-	-	27	-	-	-	-	-	Negative
Mobile phone room	-	-	-	-	(4)	-	-	2.2	-	-	-	-	-	Neutral
Office + Warehouse	20	-	-	-	(4)	-	-	2.2	-	-	-	-	-	Negative
Clean room	-	-	-	-	(4)	-	-	18	-	-	-	-	-	Negative
HV switchboard, LV main switchboard, power	40	40	-	-	(7)	-	-	(7)	-	-	-	-	-	Positive

Room Name	Room Temperature		Relative Humidity	Fresh Air Volume		Direct Exhaust			Air Change Number	Occupancy		Lighting Load	Electrical Load	Noise Level	Room Pressure
transformer, Internal service transformer, Emergency switchboard rooms															
Battery room	25	25	50	-	(4)	-	-	-	5	-		-	-	-	Negative
AG secondary distribution panel, Escalator panel, Low-voltage panel rooms	40	40	-	-	(4)	-	-	(7)	-	-		-	-	-	Neutral
Signalling / Communication	20 (min.)	25 (max.)	50	-	2.2 (5)	-	(5)	-	-	-		-	-	-	Positive
DC Isolation Room	40	40	-	-	(4)	-	-	(7)	-	-		-	-	-	Negative
Fibre Optics Room	25	25	50	-	(4)	-	-	2.2	-	-			-	-	-

(1) : The fresh air flow rate shall be calculated based on the critical value determined from calculations made at 4 air changes per hour and according to passenger load. An air flow rate of 0.0071 m^3/s shall be assumed per passenger. The smoke exhaust flow rate shall be determined such that, in the event of a 1-megawatt (MW) waste fire, there is a smoke-free zone of at least 2.5 metres from the floor. The same duct system shall be used for both smoke extraction and fresh air supply.

(2) : To be determined based on the critical velocity.

(3) : Two people per room shall be assumed.

(4) : In areas where the fresh air supply is up to 300 m^3/h, a door grille or a wall grille with a fire damper may be used for the fresh air supply.

(5) : A minimum of 150 m^3/h shall be provided per room.

(6) : In areas where the supply air volume is up to 300 m^3/h, a door grille may be used for the supply air.

(7) : To be determined based on heat gain.

(8) : Toilets and urinals shall be counted as one unit each, and washbasins as half a unit.

(9) : Make-up air shall be provided from corridors when the required air demand is met. A minimum of 1.1 m^3/h per m^2shall be used.

Tunnels and tunnel ventilation shafts may be used to supply fresh air for the ventilation of areas located at platform level.

The fresh air supply for areas maintained at positive pressure shall be equal to the calculated design flow rate and shall be 10% higher than the exhaust air flow rate. The fresh air supply for areas maintained at negative pressure shall be equal to the calculated design flow rate and shall

be 10% higher than the exhaust air flow rate. Flow rate differences shall be taken into account in the reduced or supplemented air flow rates of enclosed corridors.

9.3.3.2. System Description

Some general considerations regarding the design of the ventilation system, which is to be designed to serve the purposes outlined above, are as follows:

- No air conditioning shall be provided in the ticket hall (controlled and uncontrolled areas, passenger corridors) and on the platforms.
- To the extent that the architectural conditions of the stations permit, natural ventilation shall be utilised to the maximum extent possible via the piston effect to remove the heat emitted by the train from the track area. To this end, the piston relief shaft to be designed shall be connected directly to the outside air in a manner that creates minimum resistance, thereby maximising the effect of natural ventilation.
- The mechanical ventilation system shall be connected to the outside air via pavement grilles and shafts, providing fresh air supply or exhaust air discharge at these points.
- The mechanical ventilation system shall be designed to also provide smoke extraction in the event of a fire.
- Heat recovery ventilation options shall be considered for office areas requiring mechanical ventilation.

9.3.3.3. Ventilation of Common Areas

Mechanical ventilation shall be provided in stations to ensure comfort, control air quality and remove heat. The mechanical ventilation system for general areas shall also be configured to provide smoke extraction in the event of a fire.

Temperature at stations follows the trend of the outside air temperature; heat transfer with the surrounding soil layer helps maintain an average temperature at the stations. The station ventilation system shall consist of the following subsystems or components:

- Platform-level ventilation system: Exhaust from general areas and smoke extraction using the same system in the event of a fire,
- Ticket hall ventilation system: Exhaust ventilation from public areas and smoke extraction using the same system in the event of a fire.

The capacity of the ventilation systems for general areas during normal operations shall be determined according to passenger numbers. Exhaust and smoke extraction shall be provided by a single fan group.

The platform area operational scenario shall be as follows:

9.3.3.3.1 Normal Operation (Platform)

Exhaust air extraction and fresh air supply from the platform shall be carried out sequentially using reversible station ventilation fans. Based on information from the air quality sensor and/or temperature sensor, the exhaust fans shall be activated to improve air quality and/or reduce temperature. The station's fresh air requirement can be met by the clean air brought in by the piston effect of the vehicle entering from the tunnel. By reversing the operation of the station ventilation fans and passing the air through a filter separated by a series of dampers, the reverse of this scenario can also be implemented.

9.3.3.3.2 Fire Operation (Platform)

In the event of a fire on the platform, fire-resistant station ventilation fans shall be activated, and the platform-level exhaust air duct shall be designed to function as a smoke extraction system. In the event of a potential train fire, the necessary smoke control shall be carried out via the tunnel ventilation system established in the stations.

The ticket hall floor operation scenario shall be as follows:

9.3.3.3.3 Normal Operation (Ticket Hall)

As on the platform level, these fans shall be activated by air quality sensors and/or temperature sensors. The system shall be designed to operate in a sequential mode for both exhaust and supply.

9.3.3.3.4 Fire Operation (Ticket Hall)

In the event of a fire, the same station ventilation fans shall activate in the ticket hall and intermediate levels of the passenger circulation area to extract smoke.

In the fan room layouts, all components shall be independently accessible and maintenance can be carried out without the need to remove other equipment. Taking into account the dimensions of the fans, arrangements for fixed or mobile lifting mechanisms for the maintenance and movement of components shall be considered in the fan room layouts.

9.3.3.4. Ventilation of Special Areas

All toilet groups, cleaning rooms, changing rooms, baby care areas, offices and storage rooms, etc., shall be grouped together as far as possible and planned to have an independent exhaust system. If baby care, changing and office-storage areas are connected to a shared fan system, non-return dampers shall be installed on the branch ducts to protect these areas from odours from other areas. For wet areas, supply air shall be drawn from adjacent areas (circulation zones)

via supply grilles installed on the doors. Where it is not possible to provide a dedicated shaft for toilet exhaust fans, the fan outlets shall be connected to the nearest main exhaust shaft.

In areas prone to odour problems and contamination risks, such as drainage and sewage pump rooms, where connection to the wet areas' shared exhaust system is not possible, an exhaust system comprising independent extractors shall be designed. These areas shall be maintained at negative pressure, and their fresh air requirements shall be met from the corridors via transfer grilles fitted to the doors.

High Voltage Room, Low Voltage Room, Transformer Room

In these rooms, mechanical cooling shall not be provided; fresh air and exhaust fan capacities shall be determined by taking into account the maximum outdoor air temperature and the permitted maximum ΔT. Where there are no specific requirements for the electrical equipment used, ventilation rates shall be determined such that the design temperature is a maximum of 40°C.

Fans serving these areas shall operate at variable speeds in response to changes in room temperature. If these rooms are planned as separate fire zones, the necessary passive fire safety measures shall be taken for the ducts entering or exiting these rooms to prevent the spread of fire. The ventilation fans serving these rooms shall be 100% redundant.

To ensure more effective ventilation in transformer rooms, the positions of the grilles shall be arranged in accordance with the transformer layout.

If the outdoor air temperatures in the city where the rail system line is to be constructed do not permit the design temperature of 40°C to be maintained via ventilation, a multi-unit air-conditioning system with variable refrigerant flow shall be designed.

Battery Rooms

Battery rooms shall be ventilated to maintain negative pressure using independent, explosion-proof exhaust fans. Fresh air shall be drawn in through transfer grilles fitted to the wall, equipped with fire dampers.

Plant Rooms (Water Tank, Pump, Fan and Standby Rooms, Service Corridors)

Fresh air shall be supplied to these rooms via independent fans, and exhaust air shall be vented. Taking into account the equipment and maintenance/repair personnel, the minimum supply air temperature shall be 8°C.

As plant rooms are considered separate fire zones, necessary passive fire safety measures shall be taken to prevent fire spread if ducts entering or exiting these rooms pass through different fire

zones. Where fresh air supply to plant rooms is provided via transfer grilles from corridors, a fire damper shall be installed behind these grilles.

For the Tunnel Ventilation Room: if the bypass system is designed in the upper part of the room, no ventilation system shall be installed; if the bypass system is provided via a separate tunnel, a ventilation system shall be installed in the room.

Escalator Panel Room, DC Isolator Room, Low-Voltage Panel Rooms

These rooms shall be equipped with independent exhaust systems to handle the heat load. However, if these rooms are adjacent or close to one another, they may be connected to the same fan. Fresh air shall be supplied via transfer grilles mounted on the walls.

Signalling and Communication Rooms

Room ventilation shall be provided by a fresh air supply fan without a backup. These rooms shall be maintained at positive pressure. There shall be no exhaust system in these rooms. Room air shall be discharged into the corridor via transfer grilles fitted with motorised fire dampers. Fresh air shall be supplied via duct-type fans and filtered.

All ventilation ducts entering or exiting the room and all transfer grilles shall be fitted with motorised fire dampers to ensure that the ventilation ducts are closed and the room is made airtight prior to gas discharge. These dampers shall have the same fire resistance rating as the walls of the volume protected by the gas extinguishing system.

Transfer Grille Flow Rate Lower Limit

In systems with transfer grilles, if the air flow rate to be transferred is 150 m^3/h or lower and there is no gas-based fire suppression system, it shall be assumed that air transfer shall be carried out through door gaps without installing a transfer grille. A grille shall be provided for higher air flow rates.

Enclosed Car Parks

Where enclosed car parks are provided within stations, the car park ventilation system shall be designed as a ductless jet fan system. Unlike traditional ducted ventilation systems, the jet fan ventilation system operates on the principle of directing air towards the main exhaust shafts via jet fans positioned at various points within the car park. Jet fans shall impart momentum by moving a small volume of air through them at high speed in an axial direction, and a thrust effect shall be created as a result of the interaction of the air with the surrounding air from the fan outlet onwards. With the aid of this effect, the air shall be directed to the desired point without the use of ducts.

The jet fan ventilation system shall be designed to meet both daily ventilation requirements and to provide smoke control in the event of a fire. Fundamentally, the car park ventilation system is expected to serve the following primary objectives.

- Ensuring that exhaust emissions are maintained at levels that do not affect human health for car park users and staff,
- Ensuring smoke control or evacuation in the event of a fire.

The Turkish Fire Protection Regulations, ASHRAE 62.1 and BS 7346-7 standards shall form the basis for determining the main fan capacities and the operational design of the system.

For the fresh air supply required in the car park design, the ramp areas opening onto the surface shall be assessed. Should analyses indicate that fresh air supply from these areas is insufficient, the use of fresh air fans may be considered.

When selecting the main fans, at least two fans shall be provided on each shaft to ensure that 50% of capacity is maintained in the event of a failure. The jet fans shall meet normal operational ventilation requirements by adjusting their speed in response to level alarms received from the CO sensors.

9.3.4. Pressurisation

The requirements for the pressurisation system for emergency escape stairwells shall be assessed separately for each station. As a result of these assessments, the system requirement shall be determined in accordance with the CFD analyses to be carried out for each station. In this context, the necessity of the pressurisation system shall be specified in the design reports to be prepared. Where deemed necessary, the relevant calculations shall be carried out in accordance with the requirements of TS EN 12101-6 and the Regulation on the Fire Protection of Buildings (BYKHY).

9.4. AIR CONDITIONING SYSTEM

The aim of this section is to outline the fundamental principles regarding the design of the station's air-conditioning system. The station's air-conditioning system shall be designed to serve the purposes specified below;

- To provide the necessary thermal conditions for the efficient operation of the station's electronic rooms,
- To ensure thermal comfort in areas of the station where personnel are present.

9.4.1. References, Standards, Regulations and Publications

The current publication dates of the references listed below shall be taken into account.

TS Standards

- TS 825 – Thermal Insulation Rules for Buildings
- TS 2164 – Rules for the Design of Heating Systems

TS EN Standards

- TS EN 12101 – Smoke and Heat Control Systems
- TS EN 12101-6 – Smoke and Heat Control Systems – Part 6: Technical Specifications for Systems Indicating Pressure Differences – Kits
- TS EN 50272-2 – Safety Rules – For Secondary Batteries and Installations – Part 2: Stationary Batteries

ASHRAE Standards

- ASHRAE 15 – Safety Standard for Refrigeration Systems
- ASHRAE 55 – Thermal Environmental Conditions for Human Occupancy
- ASHRAE 62.1 – Ventilation for Acceptable Indoor Air Quality
- ASHRAE – Handbook of HVAC Applications Chapter 15 – Enclosed Vehicular Facilities
- ASHRAE Handbook: Fundamentals

Other International Standards

- International Mechanical Code
- US Department of Transportation, Subway Environmental Design Handbook

Regulations

- Building Energy Performance Regulations
- Regulations on the Assessment and Management of Environmental Noise

Other Publications

- Institution of Mechanical Engineers (MMO), Air Conditioning Systems

9.4.2. Design Data

For outdoor conditions, information published by the MMO or TS regarding the city where the rail system line is to be located shall be used as a basis, or current values shall be obtained from the relevant city's meteorological authority.

9.4.3. Insulation Performance of Building Elements

Where stations are buried in the ground, it is not possible to use the method prescribed by TS 825 – Thermal Insulation Rules for Buildings. The provisions of the Thermal Insulation Regulations and the application of thermal insulation to building materials shall not apply; however, in the calculations of heat loss and heat gain for heated or air-conditioned spaces, the λh (thermal conductivity calculation values) specified in TS 825 shall be used.

9.4.4. Spaces with Heating and Cooling

Technical spaces such as communications, signalling, battery and fibre optic rooms shall be cooled to maintain the specified room temperatures for summer and winter, ensuring they can perform their functions regularly. Wall-mounted units shall be used as indoor air-conditioning units. Ceiling-mounted units may be used for larger capacities. As the Communications and Signalling rooms are of critical importance for operational safety, unit selection shall take into account redundancy to ensure that a failure of a single unit does not result in a reduction of more than 33% of the total capacity. There shall be no redundancy in other technical rooms.

Areas occupied by staff, such as the Station Control, Staff, Health and Prayer Rooms, shall be cooled in summer and heated in winter using split/multi-split/variable refrigerant flow multi-unit air conditioning systems to ensure thermal comfort conditions. In these rooms, if a suspended ceiling is present, four-way blow-out cassette-type units shall be used; otherwise, wall-mounted indoor units shall be used.

The air conditioning units shall be selected with heat pump functionality, and humidity control shall not be considered in these areas.

9.4.5. Spaces with Heating Only

Staff changing rooms, offices (staff rooms located near wet areas, etc.) and baby care rooms shall not be cooled due to their functions; heating requirements shall be met using self-thermostat-controlled wall-mounted and fanless electric heaters.

9.5. FIRE PROTECTION AND FIRE FIGHTING SYSTEMS

9.5.1. Introduction

This section has been prepared to explain the design principles and guidelines for fire protection and firefighting systems to be applied to all stations, tunnels and infrastructure systems within railway projects.

In all buildings and open areas along the railway line (Turkey), fire protection systems shall be designed in accordance with the Regulation on the Fire Protection of Buildings (BYKHY); where the Regulation on the Fire Protection of Buildings (BYKHY) does not contain sufficient provisions,

fire protection systems shall be designed in accordance with the relevant TS, EN and NFPA standards.

Materials with flame-spreading properties or which emit toxic gases and smoke when burning shall not be used on the railway line and in structures (such as stations).

Generators and fire pumps powered by diesel fuel shall not be used in stations.

Fire protection systems:

- Automatic gaseous extinguishing systems for Communication and Signalling rooms,
- Hydrants and fire cabinets for stations, tunnels and remote equipment rooms,
- Portable fire extinguishing system,
- The fire hydrant system in public areas, excluding commercial premises,
- The system shall be provided with the necessary fire water supply capacity and connection points via a siamese (Fire Department Connection) system.

Sprinkler systems shall cover offices and technical rooms (excluding electrical, electronic and signalling rooms), and the design of sprinklers shall be based on TS EN 12845 and/or NFPA-13, whilst the design of fire hydrants and cabinets shall be based on TS EN 671-1/2 and NFPA-14.

The pipes at the station shall be connected directly to the municipal water supply network and also to the fire water tank to be installed at the station. Furthermore, at each station, there shall be a water supply connection leading out of the station for the fire brigade. This fire brigade water supply connection shall be designed in accordance with the Fire Regulations and/or NFPA-14.

All pipes of 2 1/2” and above in the wet fire suppression system shall be threaded, whilst pipes of 2” and below shall be flanged. Furthermore, all pipes used for sprinklers, hydrants and fire hose cabinets shall be made of galvanised steel. All pipes in wet fire suppression systems where there is a risk of freezing shall be insulated, and heating shall be provided where necessary.

Fire pumps shall be independent and redundant for each station and shall be supplied from the fire water tank. Fire water tanks shall be reinforced concrete and divided into two compartments (each compartment having half the total capacity) and shall be dimensioned in accordance with the provisions of the Regulation on the Protection of Buildings against Fire. Furthermore, the compartments of the fire water tank shall be interconnected externally, and it shall be possible to use the compartments separately during maintenance via a shut-off valve. The fire water tank shall be designed to store water at the capacity specified in the regulations for the medium-risk class or as determined by hydraulic calculations. Fire pumps shall be of a capacity determined by hydraulic calculations, capable of providing the necessary flow and pressure. When performing hydraulic calculations for the tunnel hydrant, the fire pump capacity shall be determined on the

assumption that two hydrants shall be opened. Fire water tanks shall be insulated and lined with tiles up to the water level. Furthermore, the interior of the fire water tank shall be illuminated.

Fire capacity calculations shall be carried out in accordance with TS EN 12845. The fire pumps used to pressurise the stored fire water shall be electric motor-driven, and the electrical supply shall be provided from two separate sources. The fire pumps shall be of a capacity determined by hydraulic calculations and shall be capable of providing the necessary flow and pressure.

Information regarding Fire Protection Systems shall be transmitted to the FAP via Addressable Input/Output Devices (IOM), whilst the location data of monitored equipment shall be transmitted to the SCADA system via the Fire Detection System. Within the SCADA system's human-machine interfaces, a dedicated "Fire Protection" page shall be created, featuring locational and schematic diagrams of the relevant systems. Any equipment located in a position different from the required one shall be defined as an alarm for the SCADA system, and the display shall include dynamic objects in the diagrams.

Non-fire-related potential threats, such as security breaches, bomb threats, train derailments and sabotage, are outside the scope of this document.

9.5.2. References, Standards, Regulations and Publications

Fire protection design shall be carried out in accordance with the relevant provisions of the Regulation on the Fire Protection of Buildings (BYKHK); for matters not regulated by Turkish Standards, it shall be carried out in accordance with international standards. Where deemed necessary, the standards listed in the guide may be updated over time.

Local standards and regulations shall take precedence; where local standards do not provide specific requirements for rail systems relating to fire and life safety, international standards and codes shall be consulted.

Due to the nature of the rail system infrastructure, escape routes, firefighting and emergency ventilation, etc., which are linked to the specific rail system guidelines used for design purposes, are of particular importance. These specific requirements have a different design objective from that of conventional Turkish building codes.

The design of fire safety systems for all areas within the project scope shall comply with the specified standards in the following order of priority.

The standards listed below shall be used as the basis for the design of fire safety systems.

9.5.2.1. Automatic Fire Extinguishing Systems

- TS EN 12845 – Fixed Fire Extinguishing Systems: Automatic Sprinkler Systems – Design, Installation and Maintenance – Main Design Guide

- NFPA 13 – Standard for the Installation of Sprinkler Systems

9.5.2.2. Fire Cabinet Systems in Stations and Tunnels

- TS EN 671-1 Fixed Fire Extinguishing Systems – Hose Systems – Main Design Guide
- TS EN 1074-6 Valves for water supply – Part 6: Hydrants

9.5.2.3. Fire Protection Network

- Regulations on the Fire Protection of Buildings (BYKHY) – Main Design Guide

9.5.2.4. Portable Fire Extinguishers

- TS EN 3-10 – Main Design Guide
- TS EN 1866 Standard for Portable Fire Extinguishers

9.5.3. Fire Prevention

In general, the essence of fire prevention is to ensure that ignition does not occur. There are four general methods for achieving this in Rail System Tunnels, Stations and other buildings;

- Category 1: Ignition sources and hot surfaces are eliminated or reduced
- Category 2: Materials with low flammability are used wherever possible
- Category 3: Ignition sources and potential fuels are kept separate
- Category 4: The risk of spontaneous combustion is eliminated or reduced.

There are three strategic methods for fire prevention in railway structures. These are:

- Equipment (materials used)
- Design
- Operation

9.5.3.1. Equipment (Materials Used)

The materials used shall be addressed in terms of fire prevention in both the infrastructure and the vehicles (within the scope of the vehicle specifications). With regard to materials used in the infrastructure, particularly in enclosed stations and tunnels, to ensure that escape routes remain safe to use within the timeframes specified by relevant standards, all building materials used in the construction of all structures must be non-combustible. In enclosed structures, interior wall and ceiling cladding is designed to have a fire resistance class of A1, whilst floor coverings must have a fire resistance class of A1FL. The materials used shall be products that meet the requirements of the TS EN 13501 standard series.

9.5.3.2. Design

In accordance with the latest version of the Regulation on Fire Protection of Buildings, fire protection systems shall be designed in accordance with the relevant TS, EN or NFPA standards.

Detailed explanations are provided under the heading ‘Fire Protection Systems’.

9.5.3.3. Operation

Damage can be minimised by identifying, minimising and/or eliminating factors that could lead to an emergency. In the event of an incident, minimising losses and damage is only possible through the implementation of pre-prepared emergency action plans, staff training and the conduct of emergency drills. For this reason, within the scope of this project, emergency action plans shall be drawn up, staff training shall be provided and drills shall be conducted with relevant institutions and organisations.

9.5.4. Passive Fire Protection

Passive fire protection measures shall be implemented to ensure the safety of passengers and technical staff. These passive protective measures shall be carried out in accordance with NFPA 130 and NFPA 101, covering interaction with adjacent structures, the creation of fire compartments, structural protection, and the provision of passive escape routes.

The aim of passive fire protection measures is to contain the flames, smoke and toxic gases generated during a fire within a specific area, thereby delaying their spread and preventing them from affecting other areas for a certain period of time.

9.5.4.1. Interaction with Adjacent Buildings

Access routes of sufficient width shall be provided to allow fire brigade access to railway stations and depot area buildings.

Walls and floors separating the car park, shopping levels and shopping centre connection areas, as well as the vertical shafts connecting the floors (stairwells, service shafts), shall be designed to act as fire compartments.

9.5.4.2. Fire Compartments

The number and details of fire zones (compartments) vary according to the building’s service class, number of storeys and floor area. The most critical areas requiring fire resistance include: floor slabs and fire walls, electrical and mechanical service penetrations, openings to the surface, electrical and mechanical service shafts, electrical switchboard rooms, fire escape staircases and lobbies, lifts, pump and boiler rooms, and spaces containing flammable and explosive liquids.

When creating a fire compartment, criteria such as the building's usage class, fire load, fire potential, fire intensity, ease of evacuation, the ability of firefighters to effectively intervene and evacuate occupants, the floor height of the building's top storey, and sprinkler systems that influence the spread of fire or enable its complete extinguishment are taken into account. In accordance with these criteria, each of the following spaces within the building shall be arranged as a fire compartment area.

- Office floors,
- Car parks,
- Boiler rooms,
- Main electrical distribution rooms,
- Transformer stations within the building,
- Medium-voltage substations,
- Mechanical and electrical plant rooms and shafts (including escalators/conveyor belts and lifts)
- Generator room
- Control centre (security, fire automation and building automation),
- Service corridors and escape corridors,
- Fire escape staircases,

For fire compartments to be effective, the fire resistance of the elements surrounding the compartment must be continuous at the joints, and there must be no non-fire-resistant openings between compartments. Ducts and channels that play a role in the spread of fire must be insulated in such a way as not to reduce the fire resistance of the compartment. Fire-retardant materials such as cushions, mortar, coatings and mastic may be used.

To prevent the passage of fire, smoke, or both, in the horizontal and vertical transitions of water, electrical, heating, ventilation systems and similar installations from one fire compartment to another, all openings must be insulated around the installations so that no gaps remain, for a duration at least equal to the fire resistance rating of the fire compartment (wall, floor, ceiling) must be sealed against the passage of fire and smoke.

Table 9.5 specifies the required fire resistance ratings for walls, doors and openings according to station locations. Without being limited to this table, all structures shall comply with the requirements specified in NFPA 130 and NFPA 101.

Fire doors are doors that prevent the spread of fire between compartments within a building for a specified period during a fire, whilst also allowing building occupants to pass through.

Table 9.5 : Fire resistance ratings for walls, doors and openings by room type

Room Name	Fire Resistance Duration (min.)		
	Wall	Door	Opening
EMERGENCY EXIT ROUTE (emergency staircase/lift/ramp/corridor etc.)	120	90	120
BATTERY ROOM	60	60	60
LIFT LOBBY	60	60	60
DC Separator Room	60	60	60
STORAGE	60	60	60
ELECTRICAL PANEL ROOM	60	60	60
GAS EXTINGUISHER ROOM	60	60	60
GSM System Room	60	60	60
COMMUNICATIONS ROOM	120	90	120
IST. AIR CONDITIONING ROOM	60	60	60
IST. CONTROL ROOM	120	90	120
COMPRESSOR ROOM	60	60	60
CONTROLLED AREA	120	90	120
UNCONTROLLED AREA	120	90	120
OCC MAIN CONTROL CENTRE	120	90	120
OG EQUIPMENT ROOM	120	90	120
PSDS PANEL ROOM	120	90	120
Signalling Room	120	90	120
SHAFTS	120	90	120
TUNNEL AIR HANDLING ROOM	60	60	60
UPS ROOM	60	60	60
Fire Safety Hall	120	90	120
FIRE PUMP ROOM	60	60	60
YM PANEL ROOM	60	60	60
PASSENGER CORRIDOR	120	120	120

9.5.4.3. Structural Protection

The building’s load-bearing system and elements must be designed and dimensioned—both as a whole and for each individual element—to ensure they remain stable for a sufficient duration during firefighting operations to permit the evacuation of passengers and staff and the intervention of emergency services, whilst ensuring their protection throughout the fire-extinguishing process.

The fire behaviour and resistance of structural elements, including products used in conjunction with them, must be based on the relevant regulations and standards (TS EN 13501-1, TS EN 13501-2 and the Construction Products Regulation (89/106/EEC)).

9.5.4.4. Station Escape Routes

The design of escape routes in buildings must be based on ensuring that users on the train and at the station can reach a safe area as quickly and safely as possible in the event of a fire.

In all buildings, unless otherwise specified, at least two exits must be provided; the number of exits shall be determined by calculation in accordance with the relevant regulations and/or standards and shall comply with NFPA-compliant calculations.

The common route that must be traversed to reach the first exit serving this level from the end of the platform must not exceed 25 m.

Turnstiles on the station ticket hall level must be arranged so that they can move freely in the direction of escape in the event of a power failure during a fire or upon activation of the remote and/or control system.

In multi-storey and/or multi-track stations, a separate assessment shall be carried out for each platform when dimensioning escape routes. Furthermore, for areas within the building other than those serving passengers and technical staff, the user load shall be assessed based on the user load coefficients specified for different usage classes in accordance with regulations and/or standards.

9.5.5. Fire Scenario

The life and fire safety strategy for stations shall be developed in accordance with the fire scenarios provided in NFPA 130. Generally, the following fire scenarios shall be anticipated in stations:

- Train fire,
- Station fire.

9.5.5.1. Train fire

The design fire heat release rates for passenger and freight train scenarios shall be determined through a project-specific fire engineering assessment. As an initial design basis, passenger train fire scenarios shall generally be assessed within the range of 20–40 MW, while freight train fire scenarios shall be assessed within the range of 30–50 MW for non-dangerous goods traffic and higher values for dangerous goods or high fire-load cargo, where applicable.

The fire growth rate for passenger train design fire scenarios may initially be taken as medium t-squared growth, unless a more onerous growth rate is required by the project-specific fire

engineering assessment, tunnel ventilation analysis, rolling stock characteristics or applicable standards.

For freight train fire scenarios, the fire growth rate shall be determined on the basis of the transported freight type, fire load, cargo configuration, tunnel ventilation conditions and risk assessment. Medium t-squared growth may only be adopted where it is justified for the applicable freight scenario and accepted by the Engineer. For high fire-load, combustible, intermodal, tanker or dangerous goods scenarios, fast or more onerous fire growth rates shall be assessed.

The final design fire values shall be justified by the Contractor and accepted by the Engineer.

9.5.5.2. Station Fire

The fire strategy shall anticipate the following fire scenarios:

- Luggage/Rubbish Fire: A fire anticipated in areas where people are likely to be present in large numbers. This fire shall be anticipated for both platform levels and passenger area corridors.
- Fire in Staff Areas: Staff areas shall be separated from passenger spaces by fire-resistant walls. It is therefore assumed that a fire originating in these areas shall not spread to other sections.
- Commercial Area Fires: Commercial areas shall be separated from passenger spaces and from one another by fire-resistant walls. Consequently, it is assumed that a fire originating in these areas shall not spread to other zones whilst growing within the area itself. The fire load shall be determined according to the nature of the commercial areas. Where the nature of the commercial area cannot be determined, a fire load of 2.5 MW shall be assumed for the general areas of commercial floors. A smoke extraction system integrated with the station systems shall be designed for the general areas of commercial floors. With the approval of the authorities, this system may be independent.
- Technical Room Fire: Technical rooms shall be isolated from one another and from the remainder of the station by fire-resistant walls, depending on the types of equipment in the area and the potential fire risk. It shall be assumed that a fire arising in these areas shall be contained within the room and shall not spread to other spaces.

In accordance with these provisions, the anticipated fire scenarios and fire loads for stations are set out below:

- Luggage/rubbish fire and ticket hall floor fire load: 1 MW
- Commercial area fire: 2.5 MW (The fire size shall be determined according to the nature of the commercial areas. In cases where the nature of the commercial area cannot be determined, a fire load of 2.5 MW shall be assumed for the general areas of the commercial floor.)

The design shall be based on the probability of a single fire occurring at any one time.

Incidents such as train derailments, bombings, terrorist attacks, etc., are not included within the scope of the fire scenarios.

9.5.5.3. Tunnel Fire

The design fire heat release rates for passenger and freight train scenarios shall be determined through a project-specific fire engineering assessment. As an initial design basis, passenger train fire scenarios shall generally be assessed within the range of 20–40 MW, while freight train fire scenarios shall be assessed within the range of 30–50 MW for non-dangerous goods traffic and higher values for dangerous goods or high fire-load cargo, where applicable.

The fire growth rate for passenger train design fire scenarios may initially be taken as medium t-squared growth, unless a more onerous growth rate is required by the project-specific fire engineering assessment, tunnel ventilation analysis, rolling stock characteristics or applicable standards.

For freight train fire scenarios, the fire growth rate shall be determined on the basis of the transported freight type, fire load, cargo configuration, tunnel ventilation conditions and risk assessment. Medium t-squared growth may only be adopted where it is justified for the applicable freight scenario and accepted by the Engineer. For high fire-load, combustible, intermodal, tanker or dangerous goods scenarios, fast or more onerous fire growth rates shall be assessed.

9.5.6. The final design fire values shall be justified by the Contractor and accepted by the Engineer.Active Fire Protection

9.5.6.1. Automatic Sprinkler Protection

In accordance with BYKHY and NFPA 130, an automatic sprinkler system is required for the following situations:

- In accordance with NFPA 130, an automatic sprinkler system shall be provided in waste storage rooms and areas containing combustible materials, excluding railway tracks.
- In accordance with BYKHY, an automatic sprinkler system shall be provided in enclosed car parks with an area exceeding 600 m².

In general, an automatic sprinkler system shall be provided in the following areas throughout the stations:

- Medical Rooms,
- Staff Rooms,
- Offices,

- Changing Rooms,
- Fire Pump Rooms,
- Fan Rooms
- Storage Rooms,
- Prayer Room,
- Storage Rooms.

*Where the escape distances/times specified in regulations and standards cannot be met, the limits may be relaxed by implementing mechanical measures subject to the Authority's approval.

9.5.6.2. Gas Fire Suppression System

When designing the gas fire suppression system, care must be taken to ensure the system pressure is low; the necessary calculations, analyses and details regarding the gas system shall be assessed separately for each station and detailed in the relevant station fire protection reports.

The design of the gas fire suppression system shall cover the following areas throughout the station:

- Signalling Room,
- Station Control Rooms,
- OCC Control Centre,
- Other Administration or Engineer may request.

9.5.6.3. Fixed Pipe System and Fire Hydrants

The fixed pipe system shall comply with BYKHY requirements. The system shall be a water-based system. Some important conditions for the system design are given below:

- Fire hydrants shall be provided in protected areas such as fire safety lobbies or emergency escape stairwells.
- The distance from any point to a water outlet shall not exceed 60m.
- All hose connections on the fixed pipe system shall be of the Storz type, with a diameter of 50 mm or 65 mm, in accordance with the standards used by the fire service.
- A fixed pipe system shall be installed in the landing area on the platform and ticket hall levels of the emergency escape staircase.
- For fire service access, the fixed pipe system shall not be located more than 18 m from an area accessible to a fire engine.

Fixed pipe systems in tunnels and stations shall be designed in accordance with standard requirements. Fixed pipe systems shall comply with the TS EN 1074-6 standard and the connection requirements of the local fire service standard.

Fire hydrants in stations shall comply with BYKHY requirements. Fire hydrants shall be designed in accordance with the TS EN 671-1 standard. Some key features of the system are as follows:

- The distance between fire hydrants shall not exceed 30 m (for areas with a sprinkler system, this distance may be 45 m).
- Fire hydrants shall be provided for areas located on emergency escape routes and leading to fire-protected sections.
- Pressure-reducing valves shall be used if the design pressure of the fire hydrant exceeds 900 kPa.
- Fire hydrants installed on the platform level shall be fitted with a fire brigade water intake. Fire hydrants installed on the ticket hall level shall not be fitted with a fire brigade water intake.

9.5.6.4. Fixed Pipe System (Hydrant Systems)

Hydrant systems shall be designed in accordance with BYKHY.

The hydrant system to be installed within the tunnel shall be of the wet pipe type. Necessary measures shall be taken to prevent freezing. A total of 1900 l/min, DN 65 Storz-connected hose outlets shall be installed within the tunnel, allowing for the simultaneous use of two outlets by the fire brigade. The minimum outlet pressure of the hydrant shall be 6.9 bar, and the maximum shall be 12.1 bar. Fire hydrant connections shall be located within the walkway area of all main pipeline connection tunnels. The distance between fire hydrants shall be 45 metres. An isolation valve shall be installed every 245 metres along the hydrant line. Pipes with a diameter of less than 6” shall not be used in the hydrant system.

Fire equipment cabinets serving the hydrants shall be designed to be located at suitable points within the tunnel (connecting tunnels) and shall contain hose valves, portable fire extinguishers, fire hoses and hose reels. Each cabinet shall be fitted with a warning light. The hose couplings to be used for the hydrant system shall be of the Storz type, with a diameter of 50 mm or 65 mm, in accordance with the standards used by the fire service.

Fixed pipe systems shall comply with the TS EN 1074-6 standard and the connection requirements of the local fire service standard; the system design shall refer to NFPA 130 for provisions specific to rail systems.

9.5.6.5. Portable Fire Extinguishers

Portable fire extinguishers shall be installed throughout the station in accordance with BYKHY requirements. Portable fire extinguishers shall be positioned at a height of approximately 90 cm – 150 cm above the floor, in locations as close as possible to exit points where they are easily visible and accessible.

The capacities of the fire extinguishers to be used in the stations are specified below;

- 6 kg ABC-type dry chemical powder fire extinguisher (inside fire cabinets and in mechanical and technical rooms, etc.)
- 5 kg CO_2 fire extinguisher (electrical rooms, etc.)
- 30 kg CO_2 fire extinguisher (transformer and MV/LV rooms, etc.)
- 50 kg ABC-type dry chemical powder wheeled fire extinguisher (car parks, etc.).

9.5.6.6. Water Supply

The municipal water supply shall not be considered a reliable water source. Consequently, water-based fire-extinguishing systems requiring water tanks and fire pump stations shall be provided. In accordance with TS EN 12845, shared water sources may be designed to supply multiple fixed fire-extinguishing systems, such as shared fire cabinets, hose reels and sprinkler systems.

Where combined systems are used, these shall be designed to meet the requirements of TS EN 12845 and the Turkish Fire Protection Regulations. In accordance with TS EN 12845 and the Turkish Fire Protection Regulations, combined systems shall meet the following conditions:

- Calculated to be fully compliant with the design standards specified above;
- The supply must be capable of providing the total of the maximum flows calculated simultaneously for each system. Flows shall be adjusted according to the pressure required by the most demanding system.
- The supply duration shall not be less than that required for the most critical system;
- Dual pipe connections must be installed between water sources and the systems;
- If the fire hydrant system is connected to the sprinkler system, such connections must be made directly to the main outlet pipe.
- Water tanks shall be reinforced concrete and double-walled.

9.6. PLUMBING SYSTEM

This section shall primarily cover the following topics and systems;

- Clean Water System
- Wastewater System

- Drainage System

9.6.1. References, Standards, Regulations and Publications

The current publication dates of the publications listed below shall be taken into account.

TS Standards

- TS 1258 – Calculation Rules for Clean Water Plumbing
- TS EN Standards
- TS EN 806 – Building Services – Requirements for the Conveyance of Drinking and Domestic Water
- TS EN 12056 – Gravity Drainage Systems

9.6.2. Potable Water System

At the station, a clean water plumbing system shall be designed to supply cold and hot water in accordance with the requirements of the premises. Clean water shall be supplied via a connection to the municipal water network.

Water drawn from the municipal network shall pass through a shut-off valve + strainer + water meter + shut-off valve assembly, after which it shall be distributed via the service water manifold to the service water tank and fire water supply lines. A pressure gauge and pressure control valve shall be installed on the service water line, including the tank filling lines. The water meter shall be installed within a manhole as per the site plan.

A modular water tank shall be provided for the storage of cold domestic water.

Under normal operating conditions, where water quantity and pressure are sufficient, mains water shall be supplied directly to the points of use. In the event of faults or interruptions in the water network, the booster system shall automatically come into operation. The booster system shall be dual-pump (redundant) and equipped with a replaceable diaphragm expansion tank.

Water tank levels and booster system fault information shall be monitored by the SCADA system.

The criteria in TS 1258 shall be used as the basis for calculating the storage tank volume for domestic water;

For pipe sizing, the tables provided in TS EN 806-3 according to the pipe material shall be taken into account. The load units for fittings according to TS EN 806 are given below.

Table 9.6 : Potability water system load units

PLACE OF USE	LOAD UNIT (LU)
Washbasin	1
Sink	2
Turkish-style toilet tap	1
Sink tap	2
Turkish/Western-style toilet cistern	1
Western-style toilet tap	1
Urinal	1

A central hot water system shall not be planned for the stations. Electric storage water heaters shall be used in the washbasins, sinks and cleaning sinks in the toilets, staff rooms, cleaning rooms, ablution rooms and baby care rooms designated for staff use, in accordance with their capacity. The final capacity of the electric water heaters shall be determined based on the number of units, taking architectural plans into account. Where washbasins in waste water pump rooms are located at a distance from the hot water supply points, electric instant water heaters shall be installed.

Hot water shall not be supplied to the washbasin groups in toilets intended for general use or to the taps in the drainage pump room.

Design Criteria

Some general considerations regarding the design of the domestic water supply system, which shall be designed to serve the purposes outlined above, are as follows:

- Domestic water storage duration (t) : 3 days
- Daily domestic water requirement : 27 litres/person, day (TS1258, Table 2)
- Potable water flow pressure (Hab) : 10 mWG (TS EN 806)
- Maximum water velocity in domestic water pipes : 3 m/s (TS EN 806)
- Hourly peak water demand coefficient (fK) : 0.3 (TS 1258, Table 21)
- Washbasin hot water requirement : 27 litres/h (TS 1258, Table 19)
- Kitchen sink and cleaning sink hot water requirement: 90 litres/h (TS 1258, Table 19)
- Hot water simultaneous usage factor (fE) : 0.25–1.00 (TS 1258, Table 19)
- Hot water storage factor (fD) : 0.60 (TS1258, Table 19)

9.6.3. Wastewater System

The wastewater system at the stations shall be designed in accordance with TS EN 12056. As the station structures are situated below the main wastewater mains, the wastewater discharge shall be planned entirely by means of pumping.

The wastewater system shall be designed primarily in accordance with the following principles;

- The gravity-fed wastewater system design shall be such that partially filled branch discharge pipes operate at a 50% fill rate (TS EN 12056 System 1)
- Primary venting configurations shall be preferred (TS EN 12056-2 Section 4.3.1)
- The following values shall be used for pipe gradients in the design of the gravity-fed waste water system;
- All pipes shall have a minimum gradient of 2%.
- In cases of structural or architectural constraints, a 1% gradient shall be considered for main pipes.
- At least flame-retardant PVC pipes shall be used for horizontal runs passing through walls and floors.
- For pressurised pipes and exposed pipes, the design shall utilise galvanised pipes. Fire-stop collars shall be provided for vertical transitions between floors.

The drains from air conditioning units shall be connected to the nearest drain, grate or sink trap. All indoor units shall be connected to the drain line via an independent trap, and the system shall be designed to operate by gravity.

The discharge units and pipe connection diameters for the sanitary drainage system at the points of use are as follows. (TS EN 12056-2, Table 2)

Table 9.7 : Characteristics of Sanitary Ware in Wastewater Plumbing

TYPE OF VITRIFIED CERAMIC	DRAINAGE RATE (LITRES/SEC)	PIPE CONNECTION DIAMETER (MM)
Washbasin	0.50	Ø50
Sink	0.80	Ø50
9-litre cistern toilet	2.50	Ø100
Urinal	0.50	Ø50

Floor mat washing (shower without mat)	0.60	Ø50
Strainer-1	0.80	Ø50
Strainer-2	1.50	Ø70
Strainer-3	2.00	Ø100

Wastewater from all toilets, cleaning rooms, staff rooms, etc. shall be collected in the wastewater tank. A separate wastewater pit and a submersible wastewater pump shall be installed for the washbasin and leakage water in the room where the tank is located, and this water shall be connected to the discharge line of the main pumps after the check valve. The wastewater tank shall be separate from the drainage pits.

The wastewater collected in the wastewater tank shall be pumped into a wastewater manhole to be constructed at ground level using an integrated main and standby electric pump. The connection of the wastewater manhole to the municipal sewage network shall be designed within the scope of the “Infrastructure Projects”.

If a packaged system meeting the pump specifications cannot be supplied, a conventional pump pit and submersible pump system may be used.

Design Criteria

Some general considerations regarding the design of the sewage system, which shall be engineered to serve the purposes outlined above, are as follows;

- Minimum operating time of the sewage pump (tp) : 8.5 s (Accepted value)
- Sewage frequency factor (K) : 0.7 (TS EN 12056-2, Table 3)

9.6.4. Drainage System

A drainage system shall be designed at the station to collect water ingress from the outside air (rainwater), water tank drainage, fire-extinguishing system drainage and leakage water drainage.

The drainage system shall be designed primarily in accordance with the following principles;

The following values shall be used for pipe gradients in the design of gravity drainage systems;

- Pipes shall have a minimum gradient of 1%.
- At least flame-retardant PVC pipes shall be used for horizontal runs passing through walls and floors.

- The design shall provide for the use of galvanised pipes for both pressurised and exposed pipes. Fire-stop collars shall be provided at vertical penetrations between floors.

Drainage water shall be collected in drainage pits. Drainage pits shall be separate from the sewage tank/pit.

Drainage grates shall be installed at both the lower and upper levels of staircases shown on the site plan. Drainage water from escalator and lift pits, drainage grates in floor slabs, and strainers at the base of ventilation shafts open to the rain shall also be channelled into the drainage pits. If water flow in escalator and lift pits is not provided by gravity, one pump may be designed with the approval of the Building Control Officer/Authority.

Along the line; a drainage system shall be provided for the drainage of the line fire-extinguishing system and the discharge of any water that may seep into the line. The pits where track drainage is collected shall be arranged at both ends of the stations, with one at each end of the track. The water collection pits to be designed at the centre of the track shall be connected to the drainage pits at the ends of the platforms. The escalator and lift pits on the platform levels, as well as the floor drains, shall also be connected to these pits.

The drainage pits on the platform shall be designed as two-section units, comprising one sedimentation section and one retention section, each directly connected to the other.

The drainage pits installed in the ticket hall and technical room level shall be equipped with a total of two submersible-type watertight drainage pumps, comprising one main and one standby unit. These drainage pits may be constructed as single-compartment units.

The pumps located in the pump stations on the platform levels shall be selected as submersible type, comprising at least 3 units: 2 main and 1 standby.

The drainage water collected in the pits shall be pumped into rainwater gullies arranged at ground level. The connections of the rainwater gullies to the municipal rainwater network shall be designed within the scope of the ‘Infrastructure Projects’.

Each sedimentation tank shall be of sufficient size to allow adequate time for the separation of solid particles from the water based on the nominal flow rates. A cleaning weir shall be provided in the sedimentation tank to prevent floating materials from blocking the pump system or being discharged from the system.

The pumps shall be arranged to operate in an automatic sequential manner. The pumps shall operate under normal, overload and standby conditions, and the operating status of the pumps shall be changed after each operation.

Where possible at viaduct stations, the drainage system shall be connected to the Local Water and Sewerage Authority's stormwater network by gravity.

Design Criteria

Some general considerations regarding the design of the drainage system, which shall be designed to serve the purposes outlined above, are as follows;

- Underground seepage coefficient in the tunnel (Ws): 1.4 litres/minute/km
- Rainfall intensity (R): To be obtained from the relevant city's meteorological data.
- Surface runoff coefficient (C): 1.0
- Fire water flow rate for the ticket hall; total of 2 x DN25 hoses: 12 m^3/h
- Platform/tunnel fire water flow rate; total of 2 DN65 hydrants: 114 m^3/h
- Settling time (tS): 6 min (1/10 h) (Assumption)
- Minimum operating time of the drainage pump (tp): 4 min (1/15 h) (Assumption)

9.7. ESCALATORS AND LIFTS

In addition to the design criteria given in Section 6.4 for escalators and lifts, the main design parameters are given in the tables below:

Table 9.8 : Main Design Parameters for Escalators

Description	**Relevant Standard and Values**
Number of loading/safety levels	EN115-1
Type	Two-speed - two-way, heavy-duty type
Incline angle	30°
Step speed	0.65 m/s when carrying passengers 0.20 m/s when unoccupied
Step width	1000 mm (min)
Step depth	400 mm (min)
Height between two steps on a slope	210 mm (max)
Number of flat steps at the landing	3 steps (if height <10m) 4 steps (if height ≥10 m)
Clearance between two steps	4 mm (max)
Stair width from the bottom of the handrail	1100 mm (nominal)

Description	Relevant Standard and Values
Variation between step speed and handrail speed	0% – 2%
Clearance between the side of the steps and the stair tread	4 mm on each side, total 7 mm
Handrail	Stainless steel
Curvature radius Transition from the slope to the horizontal Transition from the slope to the horizontal above	 2000 mm At least 2600 mm (if height < 10 m) At least 3000 mm (if height > 10 m)

Table 9.9 : Main Design Parameters of Lifts

Description	Requirements
Design standards, loads and safety factors	EN 81-1, EN 81-70 and equivalent other National & International Standards
Type	The gearless electric motor type without a machine room shall feature a disc-type brake mounted on the same shaft as the motor and shall operate on DC power.
Dimensions	Architectural design and EN Standards
Drive System	Closed-loop frequency-controlled, gearless motor unit and counterweight
Capacity	1000 kg (13 people), 1150 kg (15 people), 1600 kg (20 people)
Nominal Speed Height < 15 metres Height ≥ 15 metres	 1.0 m/s in both directions, speed-adjustable 1.6 m/s in both directions, speed adjustable
Operating Conditions	180 motor starts per hour, 20 hours per day, 7 days per week
Control System	Selective collective control
Docking Accuracy	±3 mm
Travel distance	Depending on station requirements
Number of floors and number of entrances/exits	According to station requirements

Description	Requirements
Cabin cladding material	Floor and ceiling in stainless steel, cabin walls in stainless steel and/or laminated glass with stainless steel frames
Docking point and door material	Laminated glass with stainless steel frames
Fire Service	As per station requirements

9.8. PLATFORM SCREEN DOOR SYSTEM (PSDS)

Where the signalling automation level on railway lines is GoA4, a PSDS design shall be implemented without exception. Where the signalling automation level is below GoA4, a PSDS design shall be implemented if requested by the Authority.

The platform screen door system to be designed shall primarily provide protection for passengers using the railway against potential hazards arising from the movements of trains arriving at, waiting on, or departing from the platform, by creating a physical separation between the metro's railway line and the station platforms. Furthermore, the aim is to ensure a rapid flow of passengers by ensuring that the platform screen door system operates in harmony with the line's signalling system, thereby achieving synchronised opening and closing with the train doors. The PSDS shall include panic-barred emergency exit doors and panic-barred platform end doors to ensure the safe evacuation of passengers in the event of an emergency.

The key parameters underlying the PSDS design are listed below;

- Platform partition doors shall be of the horizontal, centre-opening, double-sliding type. The door width shall be 2100 mm.
- The PSDS height shall be within the range of 2300–2600 mm. PSDS lengths shall be standard 'Full Length' at all stations.
- Closing force: 150 N (per leaf)
- Manual opening force: 133 N
- Door response time: ≤ 0.03 s
- Time difference between doors: ≤ 0.1 s
- PSDS's automatic re-closing time following manual release: maximum 30 seconds
- Any object larger than 8 x 40 mm (steel rod) shall trigger the obstacle detection system.
- PSDS materials shall be Class A fire-resistant materials.
- PSDS units shall be designed to operate for 18 or 20 hours a day, 365 days a year, at the minimum operational frequency specified in the train project.

The system's software and hardware shall be based on modular design and redundancy principles, ensuring full reliability, ease of maintenance, appropriate scalability, and full compatibility with the Signalling System and SCADA system.

The "Design Criteria Report", which includes design criteria for PSDS components and functions, calculation reports, structural strength analysis reports, and structural durability parameters (such as air permeability, wind load, passenger pressure forces, etc.), shall be submitted to the Authority for approval.

The PSDS structural design shall also take into account the positive and negative pressures caused by the piston effect, as well as thermal changes.

Furthermore, a Hazard Analysis Report shall be prepared and submitted, identifying factors such as potential hazards associated with the PSDS system, hazard frequency, hazard categories, potential impacts, risk coefficients, etc., and outlining the measures that can be taken against these hazards.

Each PSDS sliding door shall be fitted with a PSDS status indicator. To ensure they are visible from every point on the platform, the PSDS status indicators shall be located on the covers of the header units on the PSDS.

PSDS shall also block the train's entry and exit routes to the station, and transparent platform end doors shall be installed at both ends of the platform for access to the tunnel. On the tunnel side, a panic bar shall be fitted, along with a platform partition door system featuring an electric locking mechanism for access from the platform to the tunnel side; this system shall be equipped with transparent materials meeting the technical specifications, height requirements and aesthetic standards. The passage width shall be a minimum of 800 mm.

The filling materials of PSDS doors shall be airtight, fire-resistant, low-smoke, non-toxic and durable. Construction adhesives, filling adhesives, gaskets, insulation and non-metallic materials shall not contain radioactive components or corrosives.

PSDS doors and connecting elements shall be designed to withstand the loads exerted by passengers in accordance with passenger density. (For this purpose, the load calculation shall assume 8 people per square metre (with an average weight of 75 kg per person).)

In the event of trains bypassing a station, PSDS equipment must withstand the pressure generated at maximum operating speed.

The opening time of PSDS sliding doors shall not exceed 2.5–4.0 seconds, and the closing time shall not exceed 2.5–4.0 seconds. Opening and closing times shall be adjustable.

All cables associated with the PSDS system (power supply, signal, and control cables) shall be fire-resistant for a minimum of 3 hours (FE 180), non-toxic, interference-resistant, and non-flammable.

All PSDS equipment, software and station controllers shall be provided with a safety level of at least SIL3.

Operating Modes;

Normal Operating Mode

This is a standard operating condition used when the system is functioning normally; when the train arrives or stops within the permitted error margin, PSDS shall receive a command from the Signalling System and perform the PSDS open/close function.

Confirmation that the train has stopped at the station, and verification of door opening or closing, shall be provided using synchronised data received from the signalling system. In short, the PSDS system shall not perform the opening/closing operation until it is definitively confirmed that the train has stopped at the station and a door opening/closing command has been received from the signalling system.

Fault Mode

In the event the system cannot be operated normally (such as the train failing to stop at the correct location, faults originating from the signalling system, a loss of connection between the signalling system and PSDS, or a fault in the PSDS unit (including situations involving one or more door faults)), the procedures for ensuring the safe execution of PSDS door opening/closing operations shall be detailed and submitted for approval by the Authority. The system shall be configured in accordance with the scenarios accepted by the Authority.

If PSDS detects an obstruction during the closing phase, it shall immediately halt the closing process and, after a 3-second delay (adjustable from 0 to 10 seconds), resume closing. If the door still cannot be locked after 3 closure attempts (this can also be adjusted differently), the PSDS shall fully open the door and provide an error notification.

A fault or error in the PSDS system running along one side of the platform at a station shall not affect the PSDS system on the other side of the platform.

Emergency Operation Mode

Platform partition doors shall operate as follows in the event of a vehicle fire within the station or a vehicle fire within the tunnel:

- In the event of a potential train fire within the station, the platform partition doors on the side where the fire has broken out shall remain open. The platform partition doors on the other track shall continue to operate in normal operating mode.
- In the event of a potential vehicle fire within the tunnel, the platform partition doors shall continue to operate in normal operating mode.

Emergency Mode operating procedures shall be defined in detail during the design phase and submitted to the Authority for approval.