

Employer's Requirements: Technical Specifications

**DESIGN, MANUFACTURE, SUPPLY, TESTING, COMMISSIONING AND
TRAINING OF 378 NOS. OF STANDARD GAUGE METRO RAIL CARS
FOR MUMBAI METRO RAIL INVESTMENT PROJECT**

CONTRACT AGREEMENT

CONTRACT 'MRS1'

PART-I

SUPPLY REQUIREMENTS

EMPLOYER'S REQUIREMENTS: TECHNICAL SPECIFICATIONS (ERTS)



000354



CONTRACT MRS1**EMPLOYER'S REQUIREMENTS: TECHNICAL SPECIFICATIONS****CONTENTS**

1.	INTRODUCTION.....	6
1.1	Scope.....	6
1.2	Prototype Train.....	7
2.	GENERAL REQUIREMENTS.....	9
2.1	General.....	9
2.2	Interface Activities.....	9
2.3	Quality Assurance.....	10
2.4	System Safety Assurance.....	10
2.5	Hazard Analysis.....	11
2.6	Fail Safe Design.....	12
2.7	Reliability, Availability and Maintainability: General.....	13
2.8	Reliability Requirements.....	14
2.9	Reliability Demonstration.....	16
2.10	Availability Requirements.....	17
2.11	Availability Demonstration.....	18
2.12	Maintainability Requirements.....	18
2.13	Maintainability Demonstration.....	20
2.14	Maintenance.....	21
2.15	Electro-Magnetic Compatibility: General.....	22
2.16	Electro-Magnetic Compatibility Requirements.....	22
2.17	Electro-Magnetic Compatibility Demonstrations.....	22
2.18	Noise and Vibration.....	23
2.19	Fire Performance.....	25
2.20	Fire Detection System.....	25
2.21	Life Cycle Cost.....	26
3.	DESIGN AND PERFORMANCE REQUIREMENTS.....	28
3.1	Scope.....	28
3.2	Proven Design.....	28
3.3	Basic Design Philosophy & Requirements.....	30
3.4	Design Management and Control.....	31
3.5	System Integration Process.....	31
3.6	Interface Management.....	31
3.7	Design Submission Requirements.....	31
3.8	Design Review.....	32
3.9	Employer's Design Audit.....	32
3.10	Climatic and Environmental Conditions.....	32
3.11	Flood Proofing.....	33
3.12	Deleted.....	33
3.13	Line Profile.....	33
3.14	Track Structure Parameters.....	33
3.15	Track Tolerances.....	34
3.16	Platform Interface.....	35
3.17	Current Collection System.....	35
3.18	Signalling System.....	36
3.19	Telecommunication System.....	36
3.20	Kinematic Envelope.....	36
3.21	Train Performance.....	37
3.22	Performance Requirements.....	39
3.23	Emergency Operating Condition.....	47
3.24	Specific Energy Consumption.....	47
4.0	VEHICLE BODY.....	56
4.1	General.....	56
4.2	Mock-ups - General.....	56
4.3	Static Vehicle Profile.....	56
4.4	Materials.....	57



4.5	Car Weight and Passenger Capacity	58
4.6	Car Body Strength	58
4.7	Equipment and Equipment Mounting	58
4.8	Crashworthiness	59
4.9	Under Floor Equipment Mounting	60
4.10	Couplers and Draft-gear	60
4.11	Car Exterior	61
4.12	Driving car Front End Exterior	62
4.13	Train Operator's Driving console	62
4.14	Saloon Interior	63
4.15	Inter-Car Gangways	69
4.16	Car Roof and Roof Mounted Equipment	70
4.17	Design of Exhaust Air Path	71
4.18	Obstruction Deflection & Derailment Detection Device (ODD)	71
5.	BOGIES	73
5.1	General Requirements and Features	73
5.2	Dynamic Requirements	74
5.3	Bogie Construction: Bogie Frame	74
5.4	Bogie Construction: Primary and Secondary Suspension	75
5.5	Bogie to Body Connection	76
5.6	Bogie Strength	76
5.7	Bogie Mounted Equipment	76
5.8	Finite Element Analysis	76
5.9	Motor Suspension	77
5.10	Gearbox and Coupling	77
5.11	Wheels, Axles and Axle-boxes	77
5.12	Bogie Brake Equipment	78
5.13	Automatic Train Control (ATC) Equipment Mounting	78
5.14	Wheel Flange Lubrication (WFL) Equipment	78
5.15	Maintainability	79
6.	PNEUMATICS, AIR SUPPLY AND BRAKE SYSTEM	81
6.1	General	81
6.2	Air Compressor and 3-Phase 415V Induction Motor Drive	81
6.3	Auxiliary Compressor	82
6.4	Air Dryer and Filtration	82
6.5	Reservoirs	82
6.6	Pressure Governors and Switches	83
6.7	Pipe System	83
6.8	Pressure Gauges	83
6.9	Levelling Valve System	84
6.10	Front Automatic Coupling Actuating Equipment	84
6.11	Ancillary Pneumatic Devices	84
6.12	Isolation of Defective Equipment	84
6.13	Brake System	84
6.14	Electric Regenerative Brake and Electric/Pneumatic Brake Blending	86
6.15	Parking Brake	87
6.16	Emergency Braking	87
6.17	Brake Control System	88
6.18	Jerk Limitation for Service Brake	89
6.19	Brake Operating Timing	89
6.20	Brake Control Under Rescue Operation	89
6.21	Failure Management	90
6.22	Wheel Slide Protection	90
6.23	Monitoring	90
6.24	Documentation	90
7.	DOOR AND DOOR CONTROL SYSTEM	92
7.1	General	92
7.2	Passenger Saloon Door	92
7.3	Front End Emergency Door/Detrainment Door	98
7.4	Cab Side Doors	99
7.5	Saloon-to-Cab Door	99
7.6	Door Leaf Construction	99
7.7	Platform Screen Door (PSD)	100
7.8	Passageway Sliding Door for 'First Class' Car	100



8.	HV AND PROPULSION EQUIPMENT.....	101
8.1	High Voltage and Propulsion Configuration.....	101
8.2	HV Power Collection.....	102
8.3	25 kV Vacuum Circuit Breaker and Earthing Switch.....	103
8.4	Lightning Arrestor.....	104
8.5	25 kV Potential Transformer (Explosion proof).....	104
8.6	AC Current Transformer.....	104
8.7	Main Transformer.....	104
8.8	25kV Cable with HV Bushing and T-connector.....	105
8.9	Power Converter – Inverter.....	105
8.10	AC Traction Motor.....	108
8.11	Neutral Section Detector.....	110
9.	AUXILIARY SUPPLY EQUIPMENT.....	112
9.1	Auxiliary Supply System.....	112
9.2	Auxiliary Converter-Inverter.....	112
9.3	Battery Charger.....	114
9.4	Back-up Batteries.....	114
9.5	Battery Box.....	116
9.6	Inverter for HVAC Ventilation.....	116
10.	TRAIN CONTROL MANAGEMENT SYSTEM.....	117
10.1	General.....	117
10.2	TCMS Architecture.....	118
10.3	Data Acquisition.....	120
10.4	Control Features.....	120
10.5	Driving Console Interface.....	122
10.6	Self-Diagnostic Features.....	123
10.7	Fault Diagnostic features.....	124
10.8	Troubleshooting Directory.....	125
10.9	Maintenance Tools.....	126
10.10	Recording Features.....	127
10.11	Wayside Wireless Communication System.....	128
10.12	Energy Consumption Measurements.....	129
10.13	TCMS - OCC interface.....	130
11.	HEATING, VENTILATION AND AIR-CONDITIONING.....	132
11.1	General.....	132
11.2	Design Criteria – Cooling and Heating Capacity of the Unit.....	132
11.3	Heating System.....	134
11.4	Roof Mounted Package Units.....	134
11.5	Air Ducts and Diffusers.....	135
11.6	HVAC Unit Compressor.....	135
11.7	Condenser and Evaporator Coil.....	136
11.8	Piping.....	136
11.9	Electrical control cubicle.....	136
11.10	Control Equipment.....	136
11.11	Emergency Inverter.....	137
11.12	Operator's Cab Air-conditioning.....	137
11.13	Earth Fault Protection.....	137
12.	ELECTRICAL AND CONTROL EQUIPMENT.....	138
12.1	General.....	138
12.2	Train Control and Operational Principles.....	138
12.3	Trainline Electrical Connections.....	140
12.4	Control equipment.....	141
12.5	Wires and Cables.....	143
12.6	Indication Circuit.....	144
12.7	Circuit Protection and Earthing System.....	144
12.8	Lighting System.....	144
12.9	Interior Illumination System.....	146
12.10	Cab Equipment.....	148
12.11	Auxiliary Machines and Drives.....	149
13.	COMMUNICATION SYSTEM.....	151
13.1	Train Communication Equipment.....	151
13.2	OCC to Train operator and On-train Public Address Communication Link.....	152
13.3	Passenger & OCC Alarm.....	152
13.4	On-train Public Address.....	153



13.5	Cab to Cab Mode.....	154
13.6	Automatic Voice Announcement System	155
13.7	Passenger Information System	156
13.8	Operation of Passenger Information and Automatic Announcement System.....	158
13.9	Passenger Saloon Surveillance System	158
13.10	PA/PIS & PSSS test.....	160
13.11	Interface	160
13.12	Set-up facilities for PA, PIS & PSSS	161
14.	MATERIAL AND WORKMANSHIP.....	162
14.1	General	162
14.2	Materials	162
14.3	Welding	162
14.4	Corrosion	163
14.5	Fasteners	163
14.6	Enclosures	163
14.7	Wiring and Cabling.....	164
14.8	Terminals and Cable Termination.....	165
14.9	Electrical Creepage and Clearance	165
14.10	Protection & Earthing	165
14.11	Circuit Design.....	166
14.12	Electronic Equipment	166
14.13	Microprocessors and Software-based Equipment	167
14.14	Software	167
14.15	Printed Circuit Board and Connectors	167
14.16	Integrated Circuits	168
14.17	Labels	168
14.18	Lubricants	168
14.19	Painting	169
14.20	Rubber Items	169
14.21	Cables and Pipes Entries Seal	169
15.	INSPECTIONS, TESTS AND TRIALS.....	170
15.1	General	170
15.2	Inspections	170
15.3	Inspection Hold Points	171
15.4	Test Planning & Procedure	171
15.5	Obligatory Tests on Prototype	171
15.6	Integrated Testing and Commissioning	173
15.7	Service Trials	175
15.8	Special Tests	175
15.9	Vehicle Body Shell	175
15.10	Bogie Tests	175
15.11	Passenger Saloon Door, Type Tests	176
15.12	Passenger Saloon Door, Routine Tests.....	176
15.13	Saloon to Cab Door Type tests.....	176
15.14	Compressor and Motor Test	176
15.15	Brake Equipment Type Tests.....	177
15.16	Complete Brake System, Type Tests	178
15.17	Complete Brake System, Routine Tests.....	178
15.18	Propulsion System Type Tests	179
15.19	Auxiliary System Type Test	179
15.20	TCMS Type Test.....	179
15.21	Roof Mounted HVAC Package Unit Type Tests	179
15.22	Complete Car HVAC System Type Tests	181
15.23	HVAC System Routine Tests	183
15.24	Emergency Operation	183
15.25	Noise and Vibration Verification.....	183
15.26	Fire Performance Verification	183
15.27	EMC Testing	184
15.28	Integrated Testing with Signalling and Train Control, and Telecommunications	184
15.29	Type Test Witness	184
	APPENDIX TA. INTERNATIONAL STANDARDS	186
	TA1 General	186
	APPENDIX TB. CAR BODY MOCK-UPS	199



000358



TB1 Car-body Mock-up199

TB2 Car-body Engineering Mock-up201

TB3 Cab Mock-up201

TB4 Cab Front End Mock-up203

TB5 Emergency De-training Device Mock-up203

TB6 Underframe Equipment Layout Mock-up203

TB7 Roof Equipment Layout Mock-up205

TB8 Door Equipment Mock-up205

TB9 Shore Supply Mock-up206

APPENDIX TC. ABBREVIATIONS207

TC1 General207

APPENDIX TD. INTERFACES BETWEEN ROLLING STOCK, SIGNALLING AND TELECOMMUNICATION CONTRACTORS.....209

TD1: INTRODUCTION209

TD1.1 Definitions and Scope209

TD2. TRAIN OPERATING MODES212

TD2.1 General System Description212

TD2.2 Unattended Train Operation-(UTO Mode)212

TD2.3 ATO Mode212

TD2.4 ATP (or Coded Manual) Mode213

TD2.5 Restricted Manual (RM) and Run On Sight (ROS) Mode213

TD2.6 Cut-out (or By-pass) Mode214

TD2.7 Standby Mode (ready, dozing, sleeping), Immobilized mode etc214

TD2.8 Identification: Train operation mode, train description and next station information.....214

TD3. INTERFACE REQUIREMENTS BETWEEN SIGNALLING, TELECOMMUNICATION AND RS CONTRACTORS.....215

TD3.1 General215

TD3.2 Rolling Stock Characteristics to be used by Signalling Contractor219

TD3.3 Signalling and Telecommunication Details to be Used by RS Contractor219

TD3.4 ATC and Radio Equipment Cubicles220

TD3.5 Antennae220

TD3.6 Speed Measurement Devices220

TD3.7 Train operator's Display221

TD3.8 Interface Between TCMS and on-board signalling Equipment and OCC221

TD3.9 Power Supply and Earthing Arrangements222

TD3.10 Telecommunications222

TD3.11 Factory Installation and Testing223

TD3.12 EMC/EMI Interface223

TD4. INTERFACE- Division of Responsibility224

Annexure 1/TD: Rolling Stock Characteristics229

APPENDIX TE. DRAWINGS AND DOCUMENTS231

TE1 General231

APPENDIX TF. SUBMITTALS232

TF1 General232

APPENDIX-TG Train Withdrawal Scenarios for 6-car Trains.....238

APPENDIX- TH Wheel Profile (RDSO Sketch No. 91146)240



1. INTRODUCTION**1.1 Scope**

- 1.1.1 This specification establishes requirements for the design, development, manufacture, supply, testing, delivery, commissioning and integrated testing of light weight fully furnished modern passenger cars with microprocessor control 3-phase induction motor drive and suitable for Unattended train operation conforming to Grade of Automation-GOA4 as specified in IEC62290-1:2006 or latest, including the training of operating and maintenance staff of the Project Owner, for line 2 and 7 of the Mumbai Mass Rapid Transit System. The trains shall initially be operated in 'GOA2/GOA3' and shall be progressively used in 'GOA4'. The underground and elevated sections have ballastless track, and at-grade sections have ballasted track. The cars shall be designed to meet the performance requirement given in Chapter 3 of this specification. The track gauges for elevated, at grade and underground corridors shall be 1435mm.
- 1.1.2 The cars required for the various Lines shall be delivered and commissioned by the Contractor at the nominated Train Maintenance Depots of the Project Owner. The Contractor shall base his Testing, Commissioning Organization and Maintenance Organization at the nominated depots.
- 1.1.3 The scope shall also include the following:
- (i) To provide all the documentation and support material associated with the operation and maintenance of the cars as specified in the tender document for all the corridors.
 - (ii) Ongoing technical support and Defects Liability coverage until the completion of the warranty period, and rectifying the defects and deficiencies as communicated by the Engineer.
 - (iii) Interfacing with other Designated Contractors who have either physical, functional or design interfaces with this contract.
 - (iv) Training of engineers, operations and maintenance staff including providing the training materials, training kits and demonstration equipment.
 - (v) Initial supply and installation of all consumables and materials required for testing, commissioning and operation.
 - (vi) To provide final drawings, design calculations and other documents including operations and maintenance manuals for review and acceptance by the Engineer.
 - (vii) To provide supporting information including samples for design development items such as mock-ups, studies and reports.
 - (viii) Supply of spares, special tools, special test and diagnostic equipment and special training equipment, in sufficient quantities to meet the maintenance requirements.
 - (ix) Preparation of documents for obtaining approvals by Employer from the appropriate statutory authorities.
- 1.1.4 Complete network will be electrified at 25kV AC single phase, 50Hz with auto-tensioned catenary and contact wire in the elevated and at-grade sections, and overhead rigid catenary in the underground section.
- 1.1.5 Following types of cars and configuration shall be adopted: -

DM : Driving Motor cars,
 T : Trailer car with pantograph
 M : Non-driving Motor cars.

The rake formation shall generally be as follows:

3 Car unit formation: *DM – T – M –
 6 Car train formation: *DM – T – M – M – T – DM*

For increase in quantity (if required):

2 Car train formation: – T – M –
 8 Car train formation#: *DM – T – M – T – M – M – T – DM*



Where:

- * automatic couplers having mechanical and pneumatic coupling (without electrical head)
 - Semi-permanent couplers
 - # In case of 8 Car formation (if required), the performance features of extra 2 Car unit (T-M) shall be suitably designed in line with ERTS sub clause 3.22.10.
- 1.1.6.1 One of the end car of train i.e. DM car shall be having more seating capacity with additional comfort features and shall be treated as 'First Class' car.
- 1.1.6.2 The 'First Class' car shall be separated from other cars of the train by means of a sliding door. Additional details on passenger capacity, seating and sliding door for 'First Class' car are mentioned in ERTS sub clause 3.21.4, 4.14.4(vi) and 7.8 respectively. Details of design for 'First Class' car shall be discussed and approved by the Engineer during design stage.
- However, the requirement of 'First Class' Car or otherwise will be reviewed and finalized during design stage, Bidder shall provide reduction in Bid Total Lump Sum Price for non-provision of 'First Class' DM car in their Financial Bid as mentioned in Part-I: Section-4: Bidding Forms: Annexure PBS to Price Bid Submission Sheet.
- 1.1.7 The scope of work includes all items of work which may be required to meet the performance requirements, trouble free and efficient operation of trains and meeting the best international practices even if not specifically mentioned in the tender specifications.
- 1.1.8 The trains may have to be operated in GoA2/GoA3 modes with driver/ attendant during initial phase of the project and shall finally be upgraded to GoA4 (UTO).
- 1.2 Prototype Train**
- 1.2.1 The prototype 6-cars train shall be supplied as per the delivery schedule.
- 1.2.2 Clearance for dispatch of the prototype trains will be granted, only after successful completion of tests at the nominated place by the Manufacturer, to the entire satisfaction of the Employer. Should any modification/ alteration based on results of the tests on the prototype be required, Contractor will be obliged to carry out necessary modifications at no additional charge on all trains.
- 1.2.3 The Contractor shall manufacture and supply complete six cars train duly equipped with test and measuring equipment and sensors, for carrying out the following tests, in addition to those specified in IEC 61133 or an accepted International Standard, on respective lines.
- (i) Oscillation test to prove the riding and stability performance of the cars - for confirming the fitness of vehicle for introduction into revenue service.
 - (ii) Performance requirement test including test of energy consumption.
 - (iii) Tests to determine the levels of interference with traction power supply and signal and telecommunication train control equipment and facilities, to prove that these are within acceptable limits.
 - (iv) Emergency Braking Distance test for AW0 and AW3 conditions under dry and wet conditions.
 - (v) WSP tests under reduced adhesion conditions.
 - (vi) Any other test considered necessary for safe running of rolling stock or desired by Employer.
- 1.3 Contractor shall seek clearance for dispatch of each train set including prototype train set from the Engineer and shall dispatch the train only after the Engineer's clearance. Clearance for dispatch of the each of balance trains can be given by the Engineer even before successful completion of tests on the prototype trains as per clause 1.2.3 above with the provision that should any modification/ alteration based on results of the above tests on the prototype or otherwise be required, contractor shall be obliged to carry out necessary modifications at no additional charge on all trains.
- 1.4 During initial phase of the project, all trains (including prototype train) shall be tested and commissioned for GoA2 modes of automation. Upgradation of all trains to GoA3/GoA4 modes shall be done subsequently (refer Note No. 6. of 'Attachment to Appendix FB-1' to 'Form of Bid'). The interface testing may have to be done separately for line 2 & 7 of Mumbai Metro.



- 1.5 In case of any contradiction in the requirements noted in different chapters of ERTS, the specifications noted in the chapters dealing with specific sub-systems shall prevail over the specifications noted in other chapters.



2. GENERAL REQUIREMENTS**2.1 General**

2.1.1 This Chapter covers the following requirements:

- (i) Interface Activities
- (ii) Quality Assurance
- (iii) System Safety Assurance
- (iv) Hazard Analysis
- (v) Reliability
- (vi) Availability
- (vii) Maintainability
- (viii) Electromagnetic Compatibility
- (ix) Noise and Vibration
- (x) Fire and Toxicity Standards
- (xi) Life Cycle Costing

2.2 Interface Activities

2.2.1 Interfaces exist between the Rolling Stock Contractor and other designated Contractors for systems, where the systems are mutually dependent, or interactive for satisfactory and safe operation. The Rolling Stock Contractor shall maintain close coordination / interface during design, manufacturing and, testing and commissioning phase with the designated Contractors, various other Contractors and Consultants who may be working in the Project, whether or not specially mentioned in the Contract. The Rolling Stock Contractor shall perform all design duties and provide all materials, equipment and labour to ensure the satisfactory accomplishment of interface of the systems for which the Rolling Stock Contractor is responsible.

2.2.2 The Rolling Stock Contractor shall submit and maintain an agreed Interface Management Plan. At all stages of the work, all interfaces shall be discussed and agreed upon between the Rolling Stock Contractor and other Designated Contractors. Interface shall be with Signalling, Communications, Power Supply, Platform Screen Door (PSD), Civil Engineering, Track-work, Depot, Pit Wheel Lathe (PWL) Contractors and other Contractors advised by the Engineer. However, the Rolling Stock Contractor shall keep the Engineer apprised in writing of all such discussions, agreements and conclusions. Refer to the Employer's Requirements - General Specification for requirements of the Interface Management Plan, its scope and other related details.

2.2.3 In certain cases, the Engineer may direct the Contractor to liaise with Designated and other Contractors through the Engineer to discuss and agree on interfaces. However, the Rolling Stock Contractor shall keep the Engineer apprised in writing of all such discussions, agreements and conclusions.

2.2.4 It will be the sole responsibility of the Contractor that interface requirements be finalized timely. Any delays and consequential implications as a result of delay in such liaisons on account of reasons attributable to the Contractor, as concluded by Engineer, shall be the sole responsibility of the Contractor.

2.2.5 It would be the responsibility of the Contractor to settle all disagreements with the Designated Contractors. If such disagreement cannot be resolved by the Contractor, despite having made all reasonable efforts, then the Contractor shall refer the matter to the Engineer for resolution with complete details with supporting documents and any other information as may be required by the Engineer. The decision of the Employer shall be final and binding on the Contractor(s).

As part of MPR (Monthly Progress Review), the Contractor shall submit the details of all interface meetings held in corresponding month in tabular form enclosing MOM of each interface meeting.

Additionally, the schedule of interface meetings planned for next month along with the agenda (major issues to be discussed) for the same shall also be submitted as part of MPR submissions.

2.2.6 A Document titled "Interfaces between Rolling Stock, Signalling and Telecommunications Contractors" detailing the interfacing requirements and division of responsibility between the identified Designated Contractors is enclosed as 'Appendix TD' to this Specification.



- 2.2.7 It will be the responsibility of the Contractor to ensure that full potential of the rolling stock capability as specified is utilized by the Signaling Contractor(s). Any dilution shall be immediately brought to the notice of Engineer. The Contractor shall advise the maximum safe speed to the Signaling Contractor so as to enable the Signaling Contractor to design their system for 80Kmph of operational speed.
- 2.2.8 The Contractor, as a part of its Management team shall mobilize at site an Interface Manager (IM) as laid down in ERGS clause 2.3.2.
- 2.2.9 The Contractor shall engage an internationally reputed consulting agency not later than six (06) months from the commencement date for assisting the Contractor in all interface activities with other designated contractors. The Contractor's proposal for engaging consulting agency with detailed terms of reference (ToR) indicating detailed scope of work of interfacing with other designated contractors, the CV of proposed Interface Consultant to be positioned at site and timely submission of interface documents to the Engineer shall be submitted to Engineer for approval not later than three (03) months from the commencement date. The above Interface Consultant of the appointed consulting agency should be mobilized to the project site office in Delhi/Mumbai not later than six (06) months from the commencement date and shall continue to remain mobilized till the target MDBF of 125,000 km is met and accepted by the Engineer.
- 2.2.10 Employer at its sole discretion may appoint an internationally reputed consulting agency starting from three (03) months of the commencement date. The consulting agency shall assist Employer in verification and approving of the interface documents, as well as other design documents submitted by the Contractor and also for testing and commissioning etc. Under this contract with the consulting agency, services of experts up to Fifty (50) man-months can be utilized by the Employer.

In addition, the appointed consulting agency or any other agency appointed by Employer may be directed by Employer to undertake specific work related activities (both at off-site as well as at site). Also, for the work related activities, Employer at its sole discretion may depute its representative(s) to off-sites for discussion, inspection, testing etc. The expenditure for the above activities shall be borne by the Contractor but overall expenditure for these activities shall not exceed equivalent expenditure for deployment of experts for cumulative period of twenty (20) man-months only.

Total expenditure (total equivalent to 70 man-months) for deployment of experts at site as well as for other above said work related activities as mentioned above shall be borne by the contractor. The payments/reimbursements by the contractor for this shall be affected in accordance with the instructions issued by the Engineer from time to time during the contract execution.

In case of under-utilization or non-utilization of man-months, a recovery at the rate as decided by the Engineer shall be made from the payables to the Contractor.

2.3 Quality Assurance

- 2.3.1 The Contractor shall submit 'Quality Assurance Plan' for review and acceptance by the Employer as specified in the Employer's Requirements: General Specification. As a part of QAP, the Quality Assurance organization, proposed to be deployed by the Contractor for manufacture, testing and commissioning and DLP period, complete with CVs of key QA personnel shall have approval of the Engineer.
- 2.3.2 The Contractor shall develop a 'Quality Assurance Programme' (QAP), structured in accordance with acceptable international standards. Adequate records of quality assurance controls shall be maintained as per QAP and in a manner to facilitate performance audits by the Engineer.
- 2.3.3 The Contractor shall be solely responsible for all the Quality Assurance functions required by the Contract. All work and material shall be produced and control in accordance with an Internationally recognised and accepted quality standard.
- 2.3.4 All deliverable items of equipment shall be of the same configuration and be totally interchangeable. Any modifications performed on later deliveries shall be applied retrospectively to equipment already installed.
- 2.3.5 Overall responsibility of quality for manufacture, testing, commissioning and DLP shall lie with the Consortium member based on whose experience and strength, the Tenderer has qualified for this tender.

2.4 System Safety Assurance

- 2.4.1 The Contractor shall submit 'System Safety Assurance Plan' for review and acceptance by the



Engineer as specified in the Employer's Requirements: General Specification.

2.4.2 The System Safety Assurance Plan shall cover design, manufacture, testing, commissioning and integrated testing, and minimising the magnitude and seriousness of events or malfunctions, which could result in injury to patrons or staff and damage to equipment or property, but cannot be completely eliminated.

2.4.3 All personnel deployed by the Contractor in DMRC premises should have undergone requisite training on safety and should have the necessary valid certification from concerned authority.

2.5 Hazard Analysis

2.5.1 The Contractor shall take lead role in the interface Hazard Analysis for train borne equipment provided by other Contractors.

2.5.2 The Contractor shall produce the Hazard Analysis Schedule for the complete train including all train borne systems and shall interface principally with the Signalling, Communication, Power Supply, Civil and Depot Contractor as well as any other Designated Contractors to obtain the information necessary, from their hazard analysis, to complete the analysis.

2.5.3 The Contractor shall, as part of the safety analysis, prepare analysis to identify Hazards and ensure their satisfactory resolution. The following analysis shall be prepared and submitted by the Contractor for the Engineer's acceptance.

- (i) Preliminary hazard analysis
- (ii) Interface hazard analysis (excluding EMI)
- (iii) Subsystem hazard analysis
- (iv) Operating hazard analysis including maintenance
- (v) Quantitative fault tree analysis
- (vi) Failure modes effects and criticality analysis (FMECA)

2.5.4 The Hazard Analysis shall be carried out in accordance with EN50126 as the primary standard, or any other internationally accepted equivalent standard in areas not adequately addressed by the former standard.

2.5.5 The Contractor shall compile a list of critical and catastrophic items identified as a result of hazard analysis, FMECA or by other means. The Contractor shall carryout the Hazard and FMECA for the following equipment / sub-systems / systems:

- (i) Bogie and Suspension
- (ii) Vehicle Body
- (iii) Transmission Drive System
- (iv) Gangways
- (v) Coupler
- (vi) Brake System
- (vii) Door System
- (viii) HVAC System
- (ix) Pneumatic System
- (x) Communication System
- (xi) HV and Propulsion System
- (xii) Auxiliary Power System
- (xiii) Control equipment
- (xiv) TCMS
- (xv) Any item as deemed necessary by the Engineer.

2.5.6 All hazard resolution by procedural control shall be cross-referenced from the Critical and



000365



Catastrophic Items List to the appropriate manuals.

2.5.7 The qualitative measures of hazard severity are defined as follows:

- (i) Hazard Category I – Catastrophic: Operating conditions such that personnel errors, environment, design deficiencies, subsystem or component failure or procedural deficiencies may cause death or system loss. The safety target shall be based on internationally accepted standards.
- (ii) Hazard Category II – Critical: Operating conditions such that personnel errors, environment, design deficiencies, subsystem or component failure or procedural deficiencies may cause severe injury to personnel, severe occupational illness or major system damage.

The safety target for the occurrence of all Category II hazards summed together shall again be based on internationally accepted standards.

- (iii) Hazard Category III – Marginal: Operating conditions such that personnel errors, environment, design deficiencies, subsystem or component failure or procedural deficiencies, may cause minor injury to personnel, minor occupational illness or minor system damage.
- (iv) Hazard Category IV – Negligible: Operating conditions such that personnel errors, environment, design deficiencies, subsystem or component failure or procedural deficiencies will not result in injury to personnel occupational illness or damage to the system.
- (v) The Contractor shall submit a Schedule for Hazard Analysis Submissions within 30 days of Commencement Date (CD) and the Preliminary Hazard Analysis shall be submitted within 6 months of Commencement Date. This draft shall include a comprehensive assessment of potential equipment failure modes during normal operating and overload conditions and assess the performance of the equipment for a range of hazard conditions. The final draft shall be submitted by the completion date of final design.

2.5.8 The Contractor shall prepare a Fire Safety Design Report for review and acceptance by the Engineer. This shall be submitted within 2 months of Commencement Date and revised and updated for the completion of the preliminary, pre-final and final design stages. The design and materials used in the cars shall conform to fire safety requirements of EN 45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions as a minimum or better international standards applicable for similar Metro for underground operations with front evacuation, subject to the acceptance of the Engineer.

The Contractor shall engage an internationally reputed agency for the audit and certification of their fire safety design report. The Contractor shall obtain Engineer's prior approval before selecting such agency. The audit report & certificate from this agency shall be submitted by the Contractor to the Engineer.

N.B. Whichever Standard is selected for meeting the Fire Safety Criteria, then that standard shall be declared, and once accepted by the Engineer its requirements shall be met consistently throughout.

2.5.9 The procedures for Operation, Maintenance, Training and the Contractor's Quality Assurance manuals shall incorporate resolution of hazards so identified from this hazard analysis. Proper cross-referencing to the hazards and resolution measures shall be provided in all these aforementioned documents.

2.5.10 The following targets norms shall be employed for the Fault Tree Analysis. These norms are subject to review by the Engineer during the detailed design stage, and mutually agreed upon.

- (i) No single point failure shall lead to fatality.
- (ii) No combination of undetected failure and double point failures shall result in fatality.
- (iii) No combination of undetected failure and single point failure shall result in major injury.
- (iv) Under no conditions except for those specifically agreed by Engineer, the train shall be rendered immobilised in section

2.5.11 Source of all failure rates employed to be indicated in the Hazard Analysis.

2.5.12 All hazard analyses submitted to the Engineer are to be standardised by the Contractor such that format and forms employed by all Sub-Contractors are the same.

2.6 Fail Safe Design

2.6.1 All equipment and systems, including software, affecting train safety and the safety of train crew and passengers, and/or identified as being "vital", shall be designed according to the following principles (Couplers, door system, brakes, propulsion power removal, PEA shall be included, as a minimum.):



- (i) Only components having a high reliability and predictable failure modes and that have operated in similar service conditions to those in Mumbai shall be used.
- (ii) Components must be utilized in such a manner that ensures that a restrictive, rather than a permissive condition will result from a component failure. (For example: brakes will apply, rather than release; train will decelerate, rather than accelerate.)
- (iii) Circuits shall be designed such that when a normally energized electric circuit is interrupted or de-energized, it will cause the controlled function to assume its most restrictive condition. (Broken wires, damaged or dirty contacts, a relay failing to respond when energized, etc., shall not result in an unsafe condition.)
- (iv) System safety equipment design must be such that any single independent component or subsystem failure results in a restrictive condition. Failures that are not independent, those failures which, in turn, always cause others, must be considered in combination as a single failure and must not cause a permissive condition.

2.6.2 During the Design Review process, the Contractor shall submit analyses for Engineer's review and approval, which demonstrate compliance with these safety principles. These analyses shall address the following issues:

- (i) Circuit design
- (ii) Hardware design (Failure Modes, Effect and Criticality Analysis)
- (iii) Electrical interference
- (iv) Software errors
- (v) System failures

2.7 Reliability, Availability and Maintainability: General

- 2.7.1 Reliability, Availability and Maintainability (RAM) requirements and goals shall be developed in terms of Mean Distance Between Failures (MDBF), percentage Availability and Mean Time to Repair (MTTR). The Contractor shall perform RAM analysis up to the point of interface with other Contractor's systems.
- 2.7.2 The Contractor shall comply with the guidelines of IEC 60300-1, IEC 60300-2 and IEC 60571 for electronic equipment, and IEC 60300-3-5 in meeting the reliability, availability and maintainability requirements of equipment.
- 2.7.3 The Contractor shall submit Reliability, Availability and Maintainability Plan as specified in the Employer's Requirements: General Specification. The Contractor shall verify, after system design have been completed, that the reliability, availability and maintainability requirement will be met.
- 2.7.4 The Employer attaches the greatest importance to the attainment of the highest possible Reliability during service of all the equipment and systems supplied and installed under this contract. The design, manufacture, installation and commissioning of the equipment as also the training of the operating and maintenance staff shall be such as to ensure near Zero Failure performance in the initial stages and that the few defects and deficiencies that may be exposed during the Service Trial and the initial reliability growth period of one year are totally eliminated in the bulk supply. It shall also ensure that trains shall not be incapacitated under any condition unless there is inevitable mechanical failure.
- 2.7.5 The Contractor shall demonstrate by quantitative methods achievement of the specified levels of reliability for the train and specific individual items of equipment.
- 2.7.6 An evolving reliability model consisting of reliability block diagrams and probability of success equations shall be developed and submitted to the Engineer for acceptance. This model shall show the relationships required for system and equipment to operate successfully. The reliability block diagrams shall include all elements essential to the successful performance of the system and the interrelationships and interface of these elements.
- 2.7.7 Reliability apportionment and prediction analysis shall be in accordance with established techniques or standards, which will be submitted for acceptance by the Engineer. The analysis shall provide predictions for each major equipment and sub-system. Predictions shall be based on actual revenue service results for identical equipment operating under service conditions and duty cycles equivalent to Mumbai MRTS, or more severe. The analysis shall be carried out in parallel with the design of the train. The relevant apportionment and prediction figures shall be part of the design submission documents for the individual equipment, sub-system and system.
- 2.7.8 Reliability Apportionment and Prediction Report shall be completed prior to build commencing and



000367



reports shall be submitted at this stage for acceptance by the Engineer, who reserves the right to require the Contractor to carry out field data collection to verify the reliability model.

- 2.7.9 The design shall ensure that passenger deboarding cases in operational trains are bare minimum and avoided to the extent possible. Any deboarding incidence will invite penalty not exceeding Rs 15 lakh. Engineer's decision to impose the penalty shall be final.

2.8 Reliability Requirements

2.8.1 Definitions:

- (i) **Relevant Failure:** A relevant failure of an item is an independent failure which results in a loss of function of that item caused by any of the following:
- A fault in an equipment or sub-system while operating within its design and environmental specification limits;
 - Improper operation, maintenance, or testing of the item as a result of the Contractor supplied documentation.
 - Failures of transient nature including those with post investigation status as 'No fault found', shall be considered as relevant failure if in the opinion of the Engineer these are attributable to rolling stock. The decision of the Engineer shall be final.
- (ii) **Non-relevant Failure:** Any failure of an item not included in the definition of relevant failure, such as the following:
- A failure caused by malfunction of other equipment or subsystem that are not supplied by the Contractor;
 - A failure caused by human error, except as noted in Relevant Failure above;
 - A failure caused by accidents not associated with the normal operation of the item. Such as collision or striking a foreign object on the right of way;
 - A failure caused by operating the equipment or sub-system outside of design or environmental specification limits.
- (iii) **Service Failure:** Any relevant failure or combination of relevant failures during revenue service operations, simulated revenue operations, or during pre-departure equipment status checkouts to determine availability for revenue service, which results in one of the following:
- Non-availability of the train to start revenue service after successful completion of pre-departure checkout;
 - Withdrawal of the train from revenue services;
 - A delay equivalent to or exceeding 3 minutes from the Schedule / Time table as noted at the destination station for the one way trip.

The discretion of declaring a train as Not-available to start revenue service after successful completion of pre-departure checkout or withdrawing a train from revenue service on account of any relevant failure rests solely with the Engineer and shall be final. The train withdrawal scenerio is placed at Appendix TG and includes possible anticipated failure scenerios which can affect safety, punctuality and passenger comfort. The train withdrawal scenerio defined in Appendix TG shall be considered as a service failure irrespective of whether the Project Owner/Employer is able to withdraw the train or not due to its operational constraints. This list shall be further developed during DLP.

- (iv) **Pattern Failure:** Repeated occurrence of three or more relevant failures of the same replaceable part, item or equipment in same manner in identical or equivalent applications when they occur at a rate which is inconsistent with the predicted failure rate of the part, item or equipment.

The detailed methodology for identification of pattern failures shall be finalized during the design stage. The decision of the Engineer shall be final.

- (v) **Mean Distance Between Failure (MDBF):** The MDBF is the ratio of the total operating distance accumulated by the total available fleet of the trains to the total number of Service Failures.
- (vi) **Mean Distance Between Component Failure (MDBCF):** The MDBCF of a system is the ratio of the total operating distance accumulated by the total population of identical items in the available fleet of the trains to the total number of relevant failures occurring within the population identical items.

2.8.2 Reliability Targets:



- (i) Reliability shall be monitored for trains under reliability verification.
- (ii) The fleet average levels of MDBF, shall be calculated every month and shall be as specified in table 2.1, shall be achieved.

Table 2.1: Reliability Targets

Duration	Minimum fleet average MDBF
	6-Car fleet
After 6 months of start of revenue service plus stabilization period of 6 months as per para (iv) of this clause	100,000
After 12 months of start of revenue service plus stabilization period of 6 months as per para (iv) of this clause	125,000

- (iii) Wherever 'MDBF' is referred in this tender specifications, it shall be read as "AVERAGE MDBF", and shall be calculated as detailed in para (v) and (vii) as under.
- (iv) Any train shall be counted as available for reliability calculations only after a stabilization period of 6 months after putting the train into revenue service.
- (v) During the period of six (06) months to seventeen (17) months of induction of first train into revenue service, the AVERAGE MDBF of all the trains under reliability verification shall be calculated for the intervening period starting from the 06 months of the induction of first train into revenue service OR start of reliability verification of respective trains (whichever is later) and up to the month in which the MDBF is being calculated.
- (vi) The AVERAGE MDBF of 100,000 km or more, calculated as per para (v) above, shall be reached at the end of twelve (12) months of introduction of first train into revenue service.
- (vii) During the period including and beyond 18 months of induction of first train into revenue service, for those trains under reliability verification that have completed six(06) months under revenue service after entering reliability verification zone, the AVERAGE MDBF at any given month will be calculated for the period of preceding six (06) months. For all other trains under reliability verification, the AVERAGE MDBF shall be calculated for the intervening period starting from the month of start of reliability verification of respective trains and upto the month in which the MDBF is calculated subject to this period being equal to or less than six (06) months. For all such trains for which this intervening period exceeds 06 months, the period of only 06 months preceding the month in which MDBF is being calculated shall be taken.
- (viii) The AVERAGE MDBF of 125,000 km or more, calculated as per para (vii) above shall be reached at the end of 18 months of introduction of first train into revenue service (including stabilization period of 6 months as per para (iv) above). If this is not met, for each month after the 18th month where the MDBF calculated as per para (vii) above is less than the targeted MDBF of 125,000 km, the warranty (DLP) period shall be extended by one (01) month.
- (ix) When the targeted AVERAGE MDBF of 125,000 km is met, this shall be maintained until the end of warranty period. After the targeted MDBF of 125,000 km is met, if in a particular month, the AVERAGE MDBF as calculated as per para (vi) above is less than 125,000 km, one additional month shall be added to the warranty period.
- (x) The achieved level of MDBCf of major systems shall be as proposed by the Contractor in the bid.
- (xi) The Tenderer shall submit MDBCf of the major systems as listed in table 2.2 along with the bid.

Table 2.2 : MDBCf of major systems

S.N	System / Equipment	MDBCf (km)
(i)	Propulsion System	
	a) Pantograph	

	b) VCB and Earthing switch	
	c) Main Transformer	
	d) Power Converter – Inverter- 1. IGBTs & other Power components 2. Control Electronics	
	e) Traction Motor	
	f) Deleted	
(ii)	Auxiliary Supply System	
	a) Auxiliary Converter-Inverter	
	b) Battery Charger	
	c) Back-up Batteries	
(iii)	Air Supply system	
(iv)	Brake system Application & Release valves Other Valves & piping etc. Electronics	
(v)	Door System, components and Controls	
(vi)	HVAC System Refrigeration systems Control Electronics	
(vii)	Communication System PIS CCTV	
(viii)	Couplers and Draft Gear	
	a) Automatic couplers	
	b) Semi permanent couplers	
(ix)	Bogies	
	a) Drive gear and coupling	
	b) Primary suspension	
	c) Secondary suspension	
(x)	Lighting System	
(xi)	TCMS	

The achievement of MDBCf shall be demonstrated twelve months after the induction of first train in revenue service. The MDBCf values shall be calculated over a moving window of preceding six months till the MDBCf values are achieved and shall be maintained till the end of DLP.

- (xii) In addition, as a part of the Reliability Apportionment and Prediction report, the Contractor shall also submit the predicted MDBCf values pertaining to Service failures for the major systems/sub-systems and derive the predicted average MDBCf for the fleet based on these predicted 'MDBCf's-Service Failures'.

2.9 Reliability Demonstration



- 2.9.1 The Contractor shall be required to establish a personal computer based Failure Reporting and Corrective Action (FRACAS) System to demonstrate compliance with specified train and equipment reliability. Any software or investigative/analytical tools required for the short term or long-term investigation/ analysis of the faults / trend shall be finalized during the design stage and complete set up for use by Project Owner/Engineer's personnel in warranty & post warranty period shall be provided in each involved depot. Software(s) shall be multiuser based. The reliability demonstration of each train shall start after six months of that train in revenue service and shall continue till the end of the defect liability period. Reliability of the trains and of the identified major systems shall be demonstrated on fleet basis.
- 2.9.2 The Employer shall collect and maintain data on every Service Failure along with the TCMS and sub system data indicating the probable failure. MDBF and MDBCf shall be calculated throughout the monitoring period. The Contractor shall collect all the relevant details from the Project Owner/Employer and submit monthly Reliability Demonstration Reports.
- 2.9.3 In case the Contractor is not able to achieve specified/provided reliability target of MDBF/MDBCf, the Contractor shall take necessary corrective measures either by way of change of design of the relevant equipment/ component or software modification.
- 2.9.4 The Contractor shall analyze and submit detail report to Engineer for each and every failure/defect of components of various equipment to determine the cause of failure and to propose corrective measures, which would be reviewed by the Engineer.
- 2.9.5 A record shall be maintained for each and every defect/failure in accordance with FRACAS as stated in Clause 2.9.1 to be submitted by the Contractor and approved by the Engineer.
- 2.9.6 Reliability shall be monitored during revenue service operation of the trains. The Contractor shall collect and collate data on each and every deficiency and failure observed by both himself and the Engineer, from handing over the first train to the end of the Defect Liability Period. Each and every failure, whether of component, sub-system or system, during this period shall be subject to a failure analysis to determine the cause of failure. The Contractor shall submit investigation reports for review of the Engineer.
- 2.9.7 Correction shall be made to components or subsystems that either fail to attain predicted reliability levels or show Pattern Failure, at no additional cost to the Project Owner/Employer.

2.10 Availability Requirements

- 2.10.1 Availability shall be assessed by the following measure:

$$\text{Percentage Availability} = 1 - \left\{ \frac{[\text{DT}(\text{SC}) + \text{DT}(\text{OPM}) + \text{DT}(\text{CM})]}{\text{Total Time}} \right\} \times 100$$

Where:

- (i) Total Time is the time in hours in the assessment period multiplied by the number of trains commissioned under the Contract.
- (ii) DT (SC), or Down Time due to service checks, is the total down time in hours due to service checks summed over all the trains commissioned under the Contract during the assessment period.
- (iii) DT(OPM), or Down Time due to Other Preventive Maintenance, is the total down time in hours due to Preventive Maintenance other than service checks, summed over all sessions carried out on all trains commissioned under the Contract during the assessment period. The trains shall not be due for major overhauls at the time of demonstration and shall therefore be excluded from the assessment.
- (iv) DT (CM), or Down Time due to Corrective Maintenance, is the total down time in hours due to corrective maintenance, summed over all sessions carried out on the trains commissioned under the Contract during the assessment period. Any unreasonable delay in handing-over the train for repairs for reasons not attributable to contractor shall be excluded. Time spent on train integrity inspections after train reformations arising from corrective maintenance work shall be included.
- (v) The down times DT(SC) and DT(OPM) shall be counted starting from the moment when the train becomes unfit for service or work is physically started on a train, whichever is earlier, and shall end when the train is restored to service condition. If the train is withdrawn from revenue service specially for service checks or other preventive maintenance, time spent on withdrawing the train and sending back the train to revenue service, if any, shall also be included.
- (vi) Down time DT(CM) shall be counted starting from the moment when the train becomes unfit for service or work is physically started on a train, whichever is earlier, and shall end when the train is restored to service condition. If the train is sent to revenue service after the corrective maintenance,



the time spent on sending back the train to revenue service, if any, shall also be included.

- (vii) The down times DT (SC), DT (OPM) and DT (CM) shall also cover the full content of the maintenance work concerned, including safety precautions, inspections, servicing, replacement of equipment, defect detection and rectification, testing and restoration to service condition.

2.10.2 Availability Target

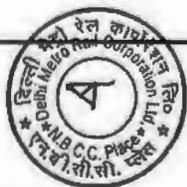
The trains supplied shall achieve a minimum average availability of 95.0%.

2.11 Availability Demonstration

- 2.11.1 The availability of trains shall generally be more than 90% during the period prior to 18 months from the start of revenue operation of the first train.
- 2.11.2 The average availability of the trains shall be assessed after 18 months from the start of revenue operation with the first train supplied under the contract, in a specified line and shall be as per ERTS 2.10.2. The total maintenance down times for all trains shall be collected by the Engineer on monthly basis, and the average availability during the preceding six months, shall be worked out from the above formula.
- 2.11.3 In the event that the availability target is not achieved, the determination of availability achievement in the preceding six month period shall be continued at monthly intervals until the target is achieved.
- 2.11.4 In the event that the availability target is not achieved, the Contractor shall, at his own expense, take whatever action is deemed necessary to meet the availability requirement.
- 2.11.5 In the event that average availability target is not achieved in any month after 18 months from start of revenue operation for the trains under reliability verification, the shortfall of trains on monthly basis (nos.) shall be included in the MDBF calculations i.e. the number of service failures in the corresponding month will be increased by the number of shortfall trains, for the purpose of MDBF calculations.

2.12 Maintainability Requirements

- 2.12.1 Simplicity of maintenance, operation and emergency procedures, ease of repair of damaged cars and equipment, are most important. These together with ease of exterior and interior cleaning will be taken into account throughout the development of the design.
- 2.12.2 Particular attention shall be paid during the design of the cars to ensure that scheduled maintenance tasks are achieved in minimum time and using minimum manpower.
- 2.12.3 Those components, systems and assemblies which require routine maintenance, frequent attention or unit replacement, shall be easily accessible for in situ maintenance.
- 2.12.4 The Contractor shall develop a comprehensive maintenance programme for the trains.
- 2.12.5 The maintenance regime proposed for the train shall be developed during the design process. A Failure Mode Effect Analysis (FMEA) will be required, based on function and derived from the specification at conceptual design stage.
- 2.12.6 At pre-final design stage the Contractor will develop this FMEA to include required maintenance derived from each failure mode. Any other maintenance required for the train should be indicated at this stage. Methodology for the deriving maintenance activities including service checks, maintenance work instructions etc. based on failure modes shall be finalized at pre-final design stage only and the same shall be further reviewed by the Engineer during the DLP period.
- 2.12.7 The vehicle shall incorporate design, which reduces maintenance, substantially improving service intervals and component replacement. The design shall also minimize mean time to repair (MTTR) and costs throughout design life. MTTR is defined as ratio of Cumulative time for repair (including the access time expended during a time interval to total number of relevant failures.
- 2.12.8 The objective of the maintainability program including corrective and preventive maintenance shall provide for:
- (i) Enhancement of Vehicle availability.
 - (ii) Minimisation of maintenance cost.
 - (iii) Minimisation of vehicle down time.
- 2.12.9 During the Pre-Final design stage, the Contractor shall furnish a list of Least Replaceable Units (LRU's) for the equipment, Sub-system and Systems supplied, which should not take more than 30 minutes for replacement. Specific exceptions, if any, whose replacement is not achievable in 30



minutes, shall be indicated by the Tenderers in their offer. In order to achieve this requirement, quick release connections such as plugs and adaptor shall be provided between LRU's and the equipment.

- 2.12.10 The Tenderer shall submit the expected MTTR of the identified key systems as listed in table 2.3 along with the bid.

Table 2.3: MTTR of major systems

S.N	System / Equipment	MTTR (hours)
(i)	Propulsion System	
	a) Pantograph	
	b) VCB and Earthing switch	
	c) Main Transformer	
	d) Power Converter – Inverter	
	e) Traction Motor	
	f) Deleted	
(ii)	Auxiliary Supply System	
	a) Auxiliary Converter-Inverter	
	b) Battery Charger	
	c) Back-up Batteries	
(iii)	Air Supply and Friction Brake Equipment	
(iv)	Door System and Controls	
(v)	HVAC System & controls	
(vi)	Communication System	
(vii)	Couplers and Draft Gear	
	a) Automatic couplers	
	b) Semi permanent couplers	
(viii)	Bogies	
	a) Drive gear and coupling	
	b) Primary suspension	
	c) Secondary suspension	
(ix)	Lighting System	
(x)	TCMS (hardware)	

- 2.12.11 During the final design stage, the Contractor shall submit periodicity, downtime and manpower requirements for the maintenance inspections and service checks considered necessary for maintaining the trains under normal operational conditions as per table 2.4. The service check sessions shall include all routine maintenance activities including inspections, cleaning, washing,



pest and rodent control etc. and shall not impact availability of trains for more than 1.5% averaged over annual basis.

Table 2.4 : Service checks

Session	Interval (Minimum)	Manpower and downtime requirements (Maximum)	
		Downtime	Expected Staff
Service Check 1			
Service Check 2, if any			
Service Check 3, if any			

Service Check n, if any			

2.12.12 The Contractor shall also submit periodicity, downtime and manpower requirements for the maintenance activities as listed in table 2.5, for maintaining the trains under normal operational conditions, during the design stage. In table 2.5, some of the values against identified activities are furnished. The Contractor shall either meet or provide better performance for these activities.

The periodicity of all overhaul activities of major items shall be synchronized with the below mentioned periodic and intermediate overhauling schedules.

Table 2.5 : Maintenance Activities

Session	Interval (Minimum)	Manpower and downtime requirements (Maximum)	
		Downtime	Expected staff
Periodic Overhaul	(8+ years)		
Intermediate Overhaul	(4+ years)	10 days	-
LRU Replacement	-	30 min	-
Corrective Maintenance operations that do not require car lifting	-	4 hours	-
Corrective Maintenance operations that require car lifting, excluding time required for shunting	-	6 hours	-

Note:

The Corrective Maintenance time as indicated above shall include defect identification, replacement of defective LRUs and restoration to service condition

2.12.13 In addition, the mid-life refurbishment period shall be specified along with complete details during design stage.

2.13 Maintainability Demonstration

2.13.1 The Contractor shall carry out tests to demonstrate that all maintainability predictions provided vide Clauses 2.12.10, 2.12.11 and 2.12.12 are met. All such tests shall be completed within twelve months after the commissioning of first train. In the event that any maintainability target is not achieved, the Contractor shall at his own expense take whatever action is deemed necessary to meet the maintainability targets.

2.13.2 The Contractor shall ensure that all the required information including the related Maintenance Work Instructions (MWI) etc. are submitted and available before the commissioning of the first train into revenue service or the commissioning last train set of the contracted quantity whichever is earlier to enable him to demonstrate the maintainability targets. The MWIs shall include details of the required materials and consumables, general tools, special tools and facilities in tabular form. All special tools and fixtures indicated in manuals shall be deemed to be included in the mandatory list of special tools under cost centre G of Annexure PBS to Price Bid Submission Sheet. Each



MWI shall be approved by the Engineer during design stage.

2.13.3 Maintenance and overhaul demonstration training of the sub-systems shall be organized within one year of the commissioning of the first train in the depot as per the approved schedule by the Engineer. Training shall include hand-on activity by the trainees. Separate spare sub-systems shall be supplied by the contractor within the quoted cost to demonstrate major overhauling. The training imparted shall include following:

- Detailed training notes (hard copy- two sets).
- Soft copy in a hard disk/ USB pen drive – for trainees (10 nos.) and additional 5 nos. for submission to the Engineer.

Training notes must include complete details of spare parts and details of tools & tackles required.

Computer based tutorials (CBT) package shall be part of the training material, which shall cover preventive maintenance and major/minor overhaul activities. CBT package shall have question bank (in sufficient numbers to choose from) for evaluation of the knowledge gained by the trainees.

Contractor shall note that the above said training shall be included in quoted cost and no additional amount would be payable. Price quoted in the cost center H do not include the above said training.

2.14 Maintenance

2.14.1 The trains shall operate with minimum attention between the specified inspection periods, and shall, under the operating conditions specified, operate between overhaul periods without requiring replacement of components other than those on the agreed list of consumable parts to be proposed by the Contractor and accepted by the Engineer.

2.14.2 Special tools shall be avoided for maintenance. If unavoidable, they shall be supplied by the Contractor in requisite quantities in all the depots to meet the maintenance requirements.

2.14.3 Equipment design shall be modular to minimise down time following failures of equipment and components. Provision for mechanical handling devices shall be provided for any single piece of equipment weighing more than 35kg and all such items shall be identified as a part of Final Design Review (FDR). Equipment covers shall be provided with secure, visible, latching arrangements easily inspectable from the side of trains.

2.14.4 All underframe equipment which cannot be handled manually shall be configured such that it can be removed and replaced from track level using fork lift trucks or lift tables, with recognition being given to the confined environment of the pit and the rail level and underframe dimensions.

All underframe equipment shall be arranged such that it is capable of being removed and replaced without disturbing any other equipment.

All such items, that may be required to be accessed and worked upon (including operation) in the event of any unusual occurrence on line shall be such mounted that it shall be very easily accessible to the train operator from PF/track level.

2.14.5 If any equipment mounted above the ceiling requires the use of lifting equipment for its removal or refitting this shall be readily achievable without the risk of damage to the vehicle interior.

2.14.6 Removal and re-assembly of moving and wearing parts on bogies shall generally be carried out without the use of special tools.

2.14.7 Bogies shall be capable of being disconnected and reconnected to vehicle bodies with a minimum of operations. All connections must be easily and safely accessible to personnel located in pits or alongside the bogie at rail level. It shall be easy to inspect for correct reconnection, from alongside the bogie where possible.

Preference will be given to a design which permits release of the bogie to permit the raising of the car body, without the need for a pit in the Lifting Berth.

2.14.8 Each vehicle shall be capable of being lifted complete with bogies without the need to attach extra restraints or supports for the bogies or wheels.

2.14.9 Lubrication points shall have button head type grease nipples, and shall be easily accessible from rail level and shall, where possible, be grouped together.

2.14.10 On-vehicle test equipment shall be used on a vehicle to discriminate between a fault on the main equipment and a fault on the control electronic equipment.



- 2.14.11 Should the electronic equipment be found to be faulty, the equipment shall enable fault finding to be carried out at module level.
- 2.14.12 Off vehicle test equipment shall be used in the depot repair centre. This equipment shall allow fault finding down to the smallest replaceable item of equipment.
- 2.14.13 The unit shall have equipment cases and modules that are connected to the main vehicle wiring via connectors which are proven in equivalent service duties to achieve high reliability and are easily removable in the event of equipment replacement.
- 2.14.14 Equipment to which access will be required for faultfinding shall be conveniently located. A list of such equipment and their location shall be supplied.
- 2.14.15 The unit shall have provision for the isolation and where applicable, earthing of all electrical sub-systems to facilitate safe and systematic maintenance and fault diagnosis.
- 2.14.16 It shall be physically impossible for plug and socket connections and connections on safety-critical circuits to be mismatched.
- 2.14.17 The unit shall have standard test points on pneumatic systems. There shall be unrestricted access to facilitate checks during routine maintenance and fault diagnosis.
- 2.14.18 The abovementioned features shall be suitably reflected in the respective design documents, as applicable, during the design stage.
- 2.15 Electro-Magnetic Compatibility: General**
- 2.15.1 An EMC Control Plan shall be submitted by the Contractor as specified in the Employer's Requirements: General Specification for review by the Engineer.
- 2.15.2 The EMC Control Plan shall include measures to reduce conducted, induced and radiated emissions to acceptable levels as specified by the relevant international standards. The plan shall specify measures to increase immunity of the train and all its subsystems.
- 2.15.3 The plan shall specify basic protective measures proposed for all electrical and electronic subsystems and components and specific measures to be adopted for selected subsystems and components.
- 2.15.4 The plan shall analyse EMI and EMC impacts on the design of the train, all other train-borne equipment and track-side equipment as well as the general environment. Particular attention should also be paid to additional requirements in grounding bonding, shielding, filtering and cabling arrangements.
- 2.15.5 The Contractor shall ensure the compatibility of the system with the power supply as available in Mumbai Metro network duly considering other trains working in the system, fluctuations/interruptions in power supply and feed extensions. Contractor shall be fully responsible for correct functioning of their system and may make suitable measurements as deemed necessary.
- 2.15.6 The Contractor shall furnish complete harmonic emission/spectrum of the fleet/train/unit in both traction and regenerative modes at Panto level on simulation studies and validate its compliance through tests with the relevant EN/IEC standards or equivalent.
- 2.15.7 The Contractor shall also furnish the details of Power Quality for the regenerated energy including its harmonic analysis.
- 2.16 Electro-Magnetic Compatibility Requirements**
- 2.16.1 All components on the vehicle shall be designed and constructed to fulfil the requirements of EN 50121 and its parts. No degradation of performance shall be permissible during the tests.
- 2.16.2 The complete 3-car unit and 6-car trains shall meet the requirements of standard EN 50121-3-1.
- 2.16.3 The Contractor shall ensure that the return current limits specified by the respective Signaling and Train Control contractors are met (see Appendix TD).
- 2.17 Electro-Magnetic Compatibility Demonstrations**
- 2.17.1 Emission (radiated and conducted) and Immunity tests for all individual equipment provided on vehicles shall be performed under normal operating condition according to EN 50121-3-2.
- 2.17.2 The conducted emission test shall be performed under selected fault condition as specified in ERTS 3.22. The conducted emission test shall also satisfy special requirements of the ATO
- 2.17.3 The complete 3-car unit, 6-car and 8 car trains (if augmented) shall be tested to meet the



requirements of standard EN 50121-3-1.

2.17.4 The Contractor shall carry out joint testing with respective Signalling and Train Control Contractors as detailed in Appendix TD.

2.18 Noise and Vibration

2.18.1 General

- (i) The Contractor shall ensure that the cars and equipment are designed and built so that specified noise and vibration limits are not exceeded. Particular attention shall be given to the design of all equipment to minimise generation of noise and vibration. The design of the vehicle shall have adequate attenuation of airborne and structural-borne vibration along potential paths from the sources to passenger saloon and to wayside receptors.
- (ii) Exterior and individual systems and equipment noise measurements are to be made in accordance with ISO 3095, and interior noise measurements are to be made in accordance with ISO Standard 3381, except where otherwise specified. For evaluation, the noise level measurements shall be as per the specified criteria below.
- (iii) Ride quality vibration measurements shall be carried out in accordance with ISO 2631-1 (1997) and ISO 2631-4(2001).
- (iv) Deleted.
- (v) For all tests, the levels of all sounds or vibrations other than those being evaluated shall be not less than 10 dB below the levels of sound being evaluated, when measure with the same weighting network of (1/3) octave bands as that being used for the test.
- (vi) Wayside noise measurements shall be performed in an essentially free field environment with no nearby structures or reflective surfaces, which could influence the measurements, by more than 2dB, other than the standard track structure and the adjacent flat, clear ground. Squealing noise shall be measured at least on two sharp curves as directed by the Engineer.
- (vii) Interior noise criteria apply to measurement within an empty full fitted car. All noise level limits specified for car interior shall also apply to interior of gangway as far as practical. The noise level shall be measured at any point along the longitudinal centreline of the gangway and at a height of 1400mm above the gangway foot-plate.
- (viii) The pad stiffness used in DMRC ballast less track is generally 29MN/m and the same shall be used for design. The noise tests during running condition shall be done in the section after six months of train operation. The Tenderer may suggest change in pad stiffness if it can help in further reducing the noise level.
- (ix) All specified noise measurements shall be revalidated 6 months before the end of DLP on a representative train selected by the Engineer. In case of non-compliance, the Contractor shall take necessary action to correct the defect and revalidate.

Provision shall be made to use wheel noise dampers. The floor, door panels and ceiling shall essentially use honeycomb or better panels for noise reduction.

Contractor shall use noise simulation software tools to predict the noise compliance to specified values. Detail simulation report shall be submitted. The report shall be submitted at first stage of design approval. References of the projects where the simulation tool has been used and actual arrived values (Corresponding to the measurement procedure specified herein) shall be submitted. Copy of the software tool shall be submitted and Engineer's representative shall be trained for use of same.

2.18.2 Noise and Vibration Assurance Plan

- (i) The Contractor shall submit a Noise and Vibration Assurance Plan as specified in the Employer's Requirements: General Specification for review by the Engineer.
- (ii) The Noise and Vibration Assurance Plan shall include:
 - Expected total car noise levels, and sub-system noise levels for all equipment and systems including Noise Simulation Report as per 2.18.1(ix) above.
 - Expected vibration levels for equipment, system and measurement locations specified herein.
 - Expected dynamic characteristics of the primary and secondary suspension.
 - Details of proposed approach to determining noise and vibration of the cars.

- All codes and standards to be used during the design and verification of the cars.
 - Plan for noise and vibration design reviews.
 - Details of proposed sub-system testing to be carried out during the design and manufacture of the cars.
 - Details of proposed rake testing to demonstrate specification compliance.
- (iii) The Plan shall be updated at each Design Stage by the Contractor and be submitted to the Engineer for review. In the Design Reviews, the Contractor shall submit noise level and vibration prediction, calculations, design information, material property information, test results and other relevant data.
- 2.18.3 Interior Noise Level shall not be more than those specified in table 2.6.

Table 2.6 : Interior Noise Levels ($L_{pAeq, 20sec}$)

Location (Section)	Interior Noise Measurements in dBA		
	Stationary		Running (Elevated/At Grade)
	Elevated/ At Grade	Undergro und	75Kmph
All cars except in driving console	68	75	75
Driving console	68	72	70

Where:

- (i) During Stationary condition, the specified limits shall be met with all auxiliary equipment operating simultaneously at maximum capacity.
 - (ii) For running conditions, the specified limits at specified speeds shall be met in elevated two track section including acceleration and deceleration) with all equipment operating simultaneously.
 - (iii) All measurements to be made along the car centre-line 1400mm above the floor and not less than 600mm from the end of the vehicle.
- 2.18.4 Door Operation Noise produced by simultaneous operation of all saloon doors on one side of the car shall not exceed 75dBA during the sliding operation and 78 dBA for the locking/unlocking, measured on the fast meter scale. This should be measured at all points in the car 300 mm from the doors and 1000 mm above floor level.
- 2.18.5 Exterior Noise Levels for elevated (measured in two track section) and at-grade sections shall not be more than those specified in table 2.7.

Table 2.7 : Exterior Noise Levels($L_{pAeq, 20sec}$)

Maximum Level of Exterior Noise in dBA	
Stationary	Running at 75Kmph
67	82

Where:

- (i) Exterior Noise level measurement to be done at a location 7.5 m horizontally from the track centreline on a horizontal plane passing through the axle centreline at any point along the length of the vehicle on either side.
 - (ii) During Stationary condition, the specified limits shall be met with all auxiliary equipment operating simultaneously at maximum capacity.
 - (iii) For running conditions, the specified limits shall be met for the entire speed range up to 75 kmph (including acceleration and deceleration) with all equipment operating simultaneously.
- 2.18.6 Noise levels obtained in underground tunnels and platforms shall be measured by the Contractor under the same conditions (as far as possible). These shall be submitted to the Engineer for reference purposes.
- 2.18.7 Vibration
- (i) The measured vibration on any portion of the car floor, walls, ceiling panels, stanchions, handholds



or seat frames shall not exceed the values specified below:

- 2.0 mm peak to peak vibration amplitude - frequency range from 1.4 Hz to 20 Hz.
- 0.8 mm per second peak vibration velocity - frequency range above 20 Hz.

(ii) All equipment, sub-assemblies and components shall be capable of withstanding shock and vibrations of the Rolling Stock satisfactorily such that they do not fail prematurely on this account earlier to the designed life. To establish this requirement, all of equipment, sub-assemblies and components shall be subjected to shock and vibration test to IEC 61373 or other relevant standards.

2.18.8 In addition to the Noise and Vibration Requirements mentioned in this ERTS, the cars and their equipment, sub-assemblies and components shall also comply with the requirements laid down in 'Guidelines for Noise and Vibrations for Metro Rail Transit Systems' issued by the Ministry of Railways, Govt. of India (Enclosed in Part-II of Tender Documents).

2.19 Fire Performance

2.19.1 General

- (i) Each train shall be designed to minimise the risk of a fire starting, as far as is practically possible.
- (ii) Materials used in the construction of each train shall be selected to reduce to the maximum extent practical the heat load, rate of heat release, propensity to ignite, rate of flame spread, smoke emission and toxicity of combustion gases.
- (iii) The train shall be designed to prevent fire propagation through the use of fire barriers in the floor, and in walls at the sides and ends and fire resistant equipment housings. Flammable materials shall be well contained with IP 65 protection. The vehicle floor shall provide a fire barrier of 30 minutes duration tested in accordance with EN45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions or better equivalent standard.

The design and the materials used in the cars shall conform to fire safety requirements of EN45545 Part 1 to 7(Category 4-A, Hazard level HL3) latest editions or better international standards for similar metro operations, subject to the acceptance of the Engineer.

- (iv) The Contractor shall submit a plan to the Engineer for review which shall describe the process that will be used to systematically identify and eliminate fire hazards, to avoid the use of combustible materials whenever practical and to reduce to the extent practical the energy content and heat release rates of the combustible material that are used.
- (v) The plan shall include the Standards to be followed and the tests to be completed and shall be submitted for review by the Engineer.

2.19.2 Material Properties

Materials used in the cars shall meet the Flammability, Smoke Emission and Toxicity requirements of the chosen Specification. (See 2.5.8)

2.19.3 The contractor shall minimize the total fire load of potentially flammable materials on a vehicle as far as is practicable, but in any case, it shall not exceed the following:

- Above floor level : 22,000 MJ
- Below floor level : 26,000 MJ

Contractor shall furnish the relevant data, fire load calculations, certifications etc. of the items considered in fire load calculations separately for Above & Below the floor level. The calculations and validation shall conform to the standard adopted by the contractor for fire strategy.

2.20 Fire Detection System:

The fire detection system shall be able to detect any fire originating inside the cars. The focus is on protection of passengers and staff in rolling stock. The objective shall be to detect incipient fires in an early stage in order to warn Train Operator/OCC. A fire event shall be detected early during the development phase, the affected area shall be located exactly by identifying which sensor(s) is actuated and further system's actions shall be activated without any delay.

In case of fire, the entire air conditioning on the train must be switched off in order to prevent any transfer of smoke to other train parts. Ventilation shall be provided depending on whether the fire/smoke has been detected inside or outside of the passenger saloon area.

2.20.1 System Design Requirements:

The fire detection system shall consist of dual smoke and heat detectors (multi-sensors) in passenger area, Linear Heat Detectors (LHD) in technical areas (enclosures/cubicles) integrated with Fire Detection & Control Unit (FDCU). The FDCU shall interface with TCMS in a redundant manner. The interface of the system shall be suitably ensured with the overall system integration and GoA4 requirements.

All the major events (alarms, faults etc.) shall be recorded in TCMS and shall be retrievable on maintenance terminal for analysing any issue.

The system shall provide a dynamic two detector dependency (smoke and/or heat) in the passenger areas along with provision of drift compensation in order to decrease the risk of false, or unwanted alarm.

Alarm sounders/ Beacons shall be provided in train at a suitable location as well as in OCC.

The Contractor shall provide necessary diagnostic tools (softwares, hardwares etc.) in order to identify failures immediately.

The system should generally be SIL2 compliant. Any change in SIL level shall be subject to the hazard analysis and acceptance or otherwise of the same by the Engineer whose decision shall be final and binding.

The system shall be able to permit addition of 2 cars, Trailer(T) and Motor(M) cars in the existing 6-car train set configuration.

2.20.2 Fire Detectors (Smoke & Heat Detectors) for passenger area:

Minimum 4 no. of Smoke & Heat detectors (multi-sensors) shall be installed in passenger area of each car. The sensitivity of smoke detector has to fulfill the requirements of ARGE guidelines. The actuating temperature of heat detector shall be settable according to the international norms and standards.

2.20.3 Linear Heat Detectors (LHD) for Enclosures/Cubicles (Electrical cabinets):

A linear heat detector suitable for Rolling Stock applications shall be provided in the electrical cabinets. The linear heat detector is to be actuated in case of any fire/overheating in the electrical cabinets.

LHD shall also be provided in Underframe Electrical enclosures as mentioned in different chapters of this document. However, final decision on use of LHD/Heat detector in Underframe Electrical enclosures will be taken during design stage.

2.20.4 Provision for bypassing any faulty/malfunctioning detector may be required, for which final decision shall be taken during design stage.

2.20.5 The number of smoke/heat detectors, LHD and their exact location may vary and shall be finalized during design stage.

The fire detection system and layout of the detectors should be able to meet the criteria for the performance to be done as per the ARGE guidelines or any other applicable international standard.

2.21 Life Cycle Cost

2.21.1 The Contractor shall develop a life cycle cost plan in accordance with IEC 300-3-3 with an aim to minimize the overall life cycle cost whilst meeting the safety, quality, availability, maintainability and reliability requirement of this particular specification.

2.21.2 The LCC shall include, the capital cost, cost of operation (including energy consumption), maintenance (both material and labour), depreciation, refurbishment, inflation etc. Per unit energy consumption cost may be considered as INR 7.0.



2.22 Deliverables

2.22.1 The Contract deliverables (tools/equipment/software etc.) required to be supplied by the Contractor under this Chapter of ERTS are listed below:

S.No.	Clause No.	Tools/Equipment/Software	Quantity
1.	2.18.1 (ix)	Noise Simulation software tools.	One set at Nominated depot.

Note:

1. The above mentioned list of deliverables is non exhaustive and only meant for the convenience for the Contractor and the Engineer.
2. The cost of these deliverables is deemed to be included in the quoted price of contract.



3. DESIGN AND PERFORMANCE REQUIREMENTS

3.1 Scope

3.1.1 This chapter outlines the broad design and performance requirements of the Rolling Stock, details of track structure, power supply system, climatic and environmental conditions, and signalling & telecommunication systems

3.2 Proven Design

3.2.1 The Contractor shall develop the design based on this specification and on sound proven and reliable engineering practices. The broad design details shall be submitted with technical data in the technical bid. Detailed calculations shall be submitted to the Engineer during the design process stage for review and approval.

3.2.2 Sub-systems other than propulsion system

The Rolling Stock, including carbody, bogies, brake system components (valves etc.) all sub-systems, equipment and major components etc. (hereinafter referred as 'sub-systems') shall be state-of-art and of proven design. Proposed sub-systems shall have been in use and have established their satisfactory performance and reliability on at least three mass rapid transit systems in revenue service over a period of three years or more (in each MRTS) either outside the country of origin in three different countries or in an MRTS in India. Sub-systems/components used in existing rolling stock of an MRTS in India do not get automatically qualified for use unless specifically approved by the Engineer for this project. If required by the Engineer, Contractor shall provide certificate of satisfactory performance for a period of three years or more from the Metro operators. Where similar sub-systems of a different rating are already proven in service as per the above criteria then the design shall be based on such sub-systems.

All 'sub systems' shall be procured from the approved vendors and sourced from only such manufacturing units that have supplied the sub-systems that fulfill the proven design requirements as above. The contract envisages commencement of manufacturing only after completion of Pre-final design. Accordingly, the number of years in revenue service and operation for the above requirements shall be calculated as on the contracted Key Date No. 3.1 corresponding to 'Pre-Final Design Completion'.

In case the contractor proposes to use sub-system(s) that do not fulfill the above said criteria then the contractor shall furnish sufficient information to prove the basic soundness and reliability of the offered sub-system(s) for review of the Engineer. The Engineer's decision on contractor's proposal shall be final and binding.

3.2.3 Propulsion System (Traction motor, Converter-Inverter and Auxiliary Converter-Inverter)

Propulsion systems manufacturer shall have at least 10 years experience of design and manufacturing of similar system. Proposed propulsion systems from the proposed manufacturing unit shall have been in use and have established their satisfactory performance and reliability for 5 years in minimum aggregate 500 cars comprising of both powered and non-powered cars, supplied either against minimum five (5) different contracts in the Metros (i.e. MRT, LRT, Sub-urban Railways and High Speed Railway) of minimum two (2) different countries outside his country of origin. If required by the Engineer, the Contractor shall provide certificate of satisfactory performance (for the supplies made from the proposed manufacturing unit) for a period of five years or more from the Metro operators. Where similar Propulsion systems of a different rating are already proven in service as per the above criteria, then the design shall be based on such systems.

Propulsion equipment shall be sourced from such manufacturing units that have supplied the equipment that fulfill the requirement of as specified above.

- (i) In case, the manufacturer of the proposed propulsion system is not a member of the Consortium/Joint venture and the contractor has indicated more than one manufacturer as the possible propulsion system supplier, final supplier out of the proposed manufacturers for the propulsion equipment shall be decided only after Employer's specific approval.
- (ii) In case the contractor proposes to use sub-system(s) that do not fulfill the above said criteria then the contractor shall furnish sufficient information to prove the basic soundness and reliability of the offered sub-system(s) for review of the Engineer. The Engineer's decision on contractor's proposal shall be final and binding.

3.2.4 Complete propulsion system comprising of converter-inverter, auxiliary converter-inverter including auxiliary supply modules and traction motor shall be from/of a single approved vendor. The Train Control and Management System (TCMS) shall either be from the qualified propulsion system



supplier (ref. ERTS 3.2.3) or from the carbody manufacturer/vehicle integrator provided the proposed TCMS is satisfactorily functioning in the metro cars as per "Attachment to Form Exp-2.1" of Part-I: Evaluation and Qualification criteria.

3.2.5 Vendor Approval

It shall be obligatory for the Contractor to obtain Notice of No Objection from the Engineer for the selection of the sub-contractor and vendors for all items of work, even if the name of the sub-contractor and vendor is named in the Contractor's Proposal and the works to be done including purchase of materials and equipment is in accordance with the Standards specified in the Contract. List of all major equipment/items of vendors shall be proposed by the Contractor during preliminary design (well before finalising the vendors), which will be reviewed by the Engineer and the Engineer may direct the contractor to include other items also for which vendor approval shall be mandatory.

The request for vendor approval shall be comprehensive with all relevant references and details establishing their compliance to the specified conditions. Along with the vendor approval proposal, a commitment from the proposed vendor shall also be submitted that in case of any future procurement action by Employer, they shall quote directly to Employer.

Contractor shall also ensure that the technical support from Sub-Contractors/Vendors of following major equipment/subsystems shall be made available through permanent positioning of Sub-Contractor's/Vendor's staff at Depots for meeting DLP obligations:

- (i) Propulsion system (including Converter-Inverter, Traction motors, Main transformer etc.)
- (ii) Auxiliary Power Supply system
- (iii) Brake and Pneumatic system
- (iv) Door
- (v) HVAC
- (vi) Bogies.

For sourcing the equipment from indigenous manufacturing facilities, following conditions shall be complied:

- (i) In case OEM wants to use manufacturing facilities in India (other than his own) for items for which the OEM has been approved, it shall enter into an agreement with such selected Indian equipment manufacturer and obtain prior approval from Employer. No change in composition, rating, type, model no., manufacturing process, quality standards, design, etc. and make of the components used in assemblies/sub-assemblies of such equipment as manufactured by the approved parent vendor shall be made without specific approval of the Engineer.
- (ii) In case the vendor uses his own facilities for indigenization after part supply of equipment from the approved manufacturing unit, no change in design, component type/make, quality standards, manufacture procedure, etc. shall be made without specific approval of the Engineer.
- (iii) In case OEM wishes to change/make/type specifications, etc. of any sub-components for supplies to be sourced from Indian facility, specific prior approval of the Engineer shall be obtained for changes made, model, specification, etc. Responsibility for obtaining such prior approval shall rest solely with the contractor. If the prior approval as per above is not obtained by the Contractor and supplies are sourced from the un-approved local Indian source then the Engineer at his sole discretion may direct the Contractor to replace equivalent no. of such items with supplies from approved sources free of cost.

Format for submitting the vendor approval request shall be given to the contractor during initial design stage and the same shall be followed throughout the contract.

3.2.6 Approval for manufacturing plant(s) for Rolling Stock

It shall be obligatory for the Contractor to obtain Notice of No Objection from the Engineer for manufacturing of tendered quantity of Rolling Stock in proposed plant(s). The plant(s) proposed by the Contractor shall have minimum five (5) years experience of manufacturing similar type of Rolling Stock as proposed for this tender. The Rolling Stock supplied from proposed plant(s) shall have been in satisfactory revenue operation for at least two (2) years.

In case Contractor proposes a new manufacturing plant(s) then the Contractor shall furnish sufficient information to prove the basic soundness and reliability of the proposal for review of the Engineer. The Engineer's decision on contractor's proposal shall be final and binding.

- 3.2.7 The overall performance of the Bidder (all members in case of JV/Consortium separately) shall be examined for all the ongoing Rolling Stock Works awarded by DMRC / any other Metro Organization (100% owned by Government) of value more than 40% of IFB cost of work and also for all the completed Rolling Stock Works awarded by DMRC / any other Metro Organisation (100% owned by Government) within last one year (from the last day of the previous month of Bid submission), of value more than 40% of IFB cost of work executed either individually or in a JV/Consortium.

The Bidder shall provide list of all such works in the prescribed Performa given in Appendix FB-18 of the Section-4: 'Form of Bid', at the time of Bid submission. The Bidder (all members in case of JV/Consortium separately) may either submit satisfactory performance certificate issued by the Client / Employer for the works or give an undertaking regarding satisfactory performance of the work with respect to completion of work/execution of work (ongoing works) failing which their Bid submission shall not be evaluated and the Bidder shall be considered non-responsive and non-compliant to the Bid conditions. In case of non-submission of either satisfactory performance certificate from Client / Employer or undertaking of satisfactory performance of any of the above work, the performance of such work shall be treated as unsatisfactory while evaluating the overall performance of Bidder in terms of Note (b) of Appendix FB-18. In case of performance certificate issued by the Client, same should not be older than three months (from the last day of the previous month of Bid submission for the ongoing works.

3.3 Basic Design Philosophy & Requirements

- 3.3.1 The design philosophy should meet the following criteria:

- (i) Application of state-of-the-art technology
- (ii) Lightweight integral car body
- (iii) Service proven design
- (iv) Design life 35 years
- (v) Crashworthiness
- (vi) Minimum life cycle cost
- (vii) Low maintenance and overhaul cost
- (viii) Use of interchangeable, modular components.
- (ix) Extensive and prominent labelling of parts and wires.
- (x) Use of unique serial numbers for traceability of components
- (xi) High reliability
- (xii) Low energy consumption
- (xiii) System safety
- (xiv) Adequate redundancy in sub-systems
- (xv) Fire, smoke detection and protection
- (xvi) Use of fire retardant materials
- (xvii) High passenger comfort including low noise level
- (xviii) Environment friendly
- (xix) Adherence to operational performance requirements
- (xx) Safe passenger evacuation in emergency
- (xxi) Maximum possible commonality of structure, components, equipment, and sub-systems amongst different cars.
- (xxii) Maximum utilisation of indigenous materials and skills, subject to quality conformity to performance requirements and quality standards.

- 3.3.2 Adequate margin shall specially be built into the design particularly to take care of the higher ambient temperatures, high humidity, dusty and corrosive conditions, etc. prevailing in Mumbai area.

- 3.3.3 Specified temperature rise of equipment shall be calculated after taking into account at least 25% choking of air filters and/or radiator fins etc. unless specified otherwise against any equipment.



- 3.3.4 All the cars supplied under this contract shall have same equipment, layout and performance and modification/rectification/retrofitting as approved by Engineer shall be implemented fleet wise. Any change shall be specifically got approved from Engineer.
- 3.3.5 The circuit design, logics, software/hardware & interfaces proposed/agreed during design will be subjected to review and updating /rectification/modification etc. during DLP based on the operational, maintenance reliability or safety requirements and generally in accordance with the contractor's proposals. In specific cases, the Engineer may issue specific instructions in writing for undertaking the modifications to meet the above requirements. In such cases, the Engineer's instructions shall be implemented as instructed. The contractor shall abide by the Engineer's instructions without any additional cost.
- 3.3.6 It will be obligatory on part of contractor to ensure that the train design incorporates and provides all necessary equipment, systems or sub systems, facilities, interface etc., generally used/provided in recent operational UTO/GoA4 trains within quoted price, notwithstanding whether these have been specifically mentioned in the ERGS/ERTS or otherwise.
In case of any necessary provision required to be incorporated in conformance to this clause, Contractor shall commit to incorporate the same into design at any stage for ensuring full compliance to this ERTS clause.
- 3.3.7 All the regulations as per "The persons with disabilities [equal opportunities, protection of rights and full participation] Act; 1995" shall be followed for the Rolling stock design, manufacture & features.
- 3.4 Design Management and Control**
- 3.4.1 In order to ensure that the requirements of this Technical Specification are met, the Contractor shall establish and maintain documented procedures using ISO 9001 to control and verify the design of the train and all its sub-systems. These procedures shall be subject to review and approval by the Engineer. Contractor shall have complete responsibility of correctness of design and its compliance with the specification.
- 3.4.2 The Contractor shall establish and maintain a systematic, documented, comprehensive, and verifiable system integration process throughout the execution of the Contract.
This process shall ensure that interfaces and interaction between cars, infrastructure, subsystems, software, and operating and maintenance requirements have been identified and engineered to function together as a system.
- 3.5 System Integration Process**
- 3.5.1 The Contractor shall systematically identify and formally document all design, manufacturing and operational interfaces between equipment within the train, and between the train and external systems, facilities, operations and the environment likely to affect or be affected by the train.
- 3.5.2 A mechanism and assigned project responsibility for interface management and control shall be provided, such that every identified interface has a defined resolution process that can be monitored.
- 3.5.3 The Contractor shall define methods to confirm compatibility between train consist sub-systems and carrying out integration tests at different stages of the design and interface management process to demonstrate that all sub-systems functions perform properly, both individually and as part of the complete train.
- 3.5.4 The Contractor shall ensure that performance, availability and safety requirements are addressed in the design process and that the reliability and maintainability of all sub-systems will enable the service performance to be met.
The system integration process shall be capable of audit by the Engineer.
- 3.6 Interface Management**
- 3.6.1 The Contractor shall submit to the Engineer for review an Interface Management Plan (IMP) and Detail Interface Documents, in accordance with the General Specification, which defines how the Contractor shall systematically identify and document technical interfaces.
- 3.7 Design Submission Requirements**
- 3.7.1 The Contractor shall perform his designs for the Contract in accordance with the General Specification. The Contractor shall submit to the Engineer for his review, relevant design information as identified under each stage. Such submissions shall incorporate the relevant international standards applicable and the copies of the applicable standards shall be submitted



along with the document.

The design submission requirements are detailed in the Employer's Requirements - General Specification.

3.8 Design Review

3.8.1 At appropriate stages in the design process, formal documented reviews of the design and related issues shall be planned and conducted. This shall be performed at fleet, train, car, system and subsystem levels, as appropriate, to verify and demonstrate:

- (i) Safety for manufacture, testing, operation and maintenance.
- (ii) Compliance with the relevant codes, specifications, the General Specification and this Technical Specification.
- (iii) Fitness for purpose, fulfilling the necessary operational functionality and performance.
- (iv) Integration and interfacing within the project and to external elements.

3.8.2 The Contractor shall submit for the Engineer's review a Design Review Schedule, in accordance with the General Specifications, which shall define the scope and timing of design reviews.

3.8.3 The Engineer reserves the right to attend any or all design reviews.

3.8.4 The Contractor shall ensure that participation in design reviews includes representatives of all functions, disciplines and entities concerned with the sub-systems and the stage being reviewed.

3.8.5 The Contractor shall at least 45 days prior to the date of each design review submit in-progress design documents of the elements to be addressed at the design review meeting.

3.8.6 The Contractor shall refer ERGS Chapter 5 for further details.

3.9 Employer's Design Audit

3.9.1 The Engineer will carry out design audits of the Contractor periodically throughout the Contract as deemed necessary for validation of the design.

Such design audits will generally cover issues related to performance, integration, co-ordination and operation and detailed design issues so far as they are considered necessary by the Engineer.

3.9.2 The Contractor shall provide all documentation and personnel participation reasonably requested by the Engineer to enable design audits to be carried out.

3.9.3 The Contractor shall within 15 days of the date of each design audit submit for review Design Audit Minutes detailing all issues raised during the audit, their resolution or ongoing design status and due date for resolution.

3.10 Climatic and Environmental Conditions

3.10.1 Extreme climatic conditions are given in Table 3.1

Table 3.1 : Climatic & Environmental Conditions

Description	Limiting Values
Maximum ambient temperature (See note 1 below)	36°C
Minimum temperature	14.3 °C
Humidity (See note 2 below)	≥95% RH
Rainfall	The annual precipitation is 2,078 mm with 34 % (709 mm) falling in the month of July.
Atmosphere during hot season	Extremely dusty including bird feathers
Maximum wind Speed	150 km/hr.



Vibration & Shocks	The sub-systems & their mounting arrangements shall be designed to withstand satisfactorily the vibration and shocks encountered in service as specified in IEC 61373 and IEC 60571.
SO ₂ level in atmosphere	80 – 120 mg/m ³
Suspended particulate matter in atmosphere	360 – 540 mg/m ³

Note:

1. The temperature of the metal surfaces of the vehicles when exposed directly to the sun, for long periods of time, may be assumed to rise to 70°C.

2. Any moisture condensation shall not lead to any malfunction or failure.

3.11 Flood Proofing

3.11.1 The traction sub-systems mounted on the under-frame will be designed to permit propulsion of the train at 10 kmph through water up to a depth of 50mm above rail level. Traction sub-systems shall be made splash proof in accordance with International Standards.

3.12 Deleted.**3.13 Line Profile**

3.13.1 The drawings showing the line profiles of all lines are enclosed.

(i) Line 2: Dahisar(E) to Mandala

(ii) Line 7: Andheri(E) to Dahisar(E)

3.13.2 All the above drawings (as referred in clauses 3.13.1) are to be found in Part-II, Supply Requirements. These drawings are currently under review. The permanent speed restrictions are also shown in the line profiles.

3.14 Track Structure Parameters

3.14.1 The Track Structure Parameters for At-grade, Elevated and Underground Corridors are set out in Table 3.2.

Table No 3.2: Track Structure Parameters

Description	Elevated and At-grade Corridor		Underground Corridor
	Ballasted	Ballast less (DFF)	Ballast less (DFF)
Track Laying Gauge	1435mm	1435mm	1435mm
Rail Type (Main Line and Depot)	60E1 (UIC 60) 880/HH	60E1 (UIC 60) 1080/HH	60E1 (UIC 60) 1080/HH
Rail Profile	UIC 861-3	UIC 861-3	UIC 861-3
Inclination Of Rail	1 in 20	1 in 20	1 in 20
Sleeper Spacing (Main Line)	600mm±10mm	600mm±10mm	700mm±10mm
Sleeper Spacing (Depot)	650mm±10mm	Not applicable	Not applicable
Ballast Cushion Depth (Main Line)	300mm	Not applicable	Not applicable
Ballast Cushion Depth (Depot)	250mm	Not applicable	Not applicable
Standard Rail Length	13m and 18m	18m	18m
Rail Panel Lengths	Longer than 200m	Longer than 200m	Longer than 200m

Minimum Radius of Curvature	200m- Underground 110m- Elevated 100m-Depot	200m- Underground 110m- Elevated 100m-Depot	200m- Underground 110m- Elevated 100m-Depot
Minimum Turn Out Radius (Main Line)	1in 9 –300m radius 1in 7 –190m radius	1in 9 –300m radius 1in 7 –190m radius	1in 9 –300m radius 1in 7 –190m radius
Minimum Turn Out (Depot)	1in 7 –190m radius	1in 7 –190m radius	1in 7 –190m radius
Maximum Cant Permissible	110 mm	110mm	110mm
Maximum Cant Desirable	110 mm	110 mm	110 mm
Maximum Cant Deficiency Permissible	85 mm	85 mm	85 mm
Maximum Cant Deficiency Desirable	85 mm	85 mm	85 mm
Maximum Permissible Cant Gradient	1 in 440	1 in 440	1 in 440
Maximum Desirable Cant Gradient	1 in 720	1 in 720	1 in 720
Turn-out Speed : Turn-out (1 in 9) R-300	45 km/h	45 km/h	40 km/h
Turn-out Speed : Scissors (1 in 9) R-300	45 km/h	45 km/h	40 km/h
Turn-out Speed : In Depots (1 in 7) R-190	35 km/h	35 km/h	25 km/h
Turn-out Speed : Turn-out (1 in 7) R-190	35 km/h	35 km/h	25 km/h
Turn-out Speed : Turn-out (1 in 12) R-410	50 km/h	50 km/h	50 km/h
Turn-out Speed : Turn-out (1 in 12) R-410	50 km/h	50 km/h	50 km/h
Turn-out Speed : Turn-out (1 in 8.5) R-218	30 km/h	30 km/h	30 km/h
Turn-out Speed : Turn-out (1 in 8.5) R-218	30 km/h	30 km/h	30 km/h
Maximum Gradient Main Line	4%	4%	4%
Maximum Gradient Depot Connection	4%	4%	4%
Minimum vertical radius of curvature	1500m	1500m	1500m

3.15 Track Tolerances

3.15.1 The Track tolerances for At-grade, Elevated and Underground Corridors are set out in Table 3.3.

Table 3.3: Track Tolerances

Description	Ballasted	Ballastless (DFF)
Laying Tolerance of Vertical Alignment measured by 20m chord (Designed level)	+ 0 to -20mm	±3mm
Alignment (Laying) on 20m chord (Horiz)	±10mm	±2mm
Cross Level Laying Tolerance (Designed) (to be measured on every 3 mtr.)	±0 to -2mm	±2mm
Twist (Other than transition curve) (to be measured on every 3 mtr base)	Straight/curve- 1mm/mtr	Straight/curve- 1mm/mtr
Cross Level Difference (Maintenance)	± 5mm	±5mm



Gauge measured at a point 14mm below crown of rail (laying) (with respect to 1435 mm)	±2mm	±2mm
Sleeper to sleeper variation of gauge (laying)	2mm	1mm
Unevenness (Maintenance) (Base 3m)	±6mm	±6mm
Alignment (Maintenance) (Base 7.5m)	±5mm	±5mm
Gauge variation maintenance (sleeper to sleeper)	+4mm to - 2mm	+4mm to - 2mm
Gauge Widening (Laying) – Tangent track ≥500m Radius, < 1000m – S.G. Track	+5mm	+5mm
Gauge Widening (Laying) – Tangent track ≥1000m Radius – S.G. track	0mm	0mm
Gauge Widening (Laying) – Tangent Track < 500m Radius – S.G. Track	+9mm	+9mm
Gauge (Maintenance) – Tangent track- S.G. track	±6mm	±6mm
Gauge (Maintenance) - ≥500m Radius, < 1000m – S.G. Track	±6mm over widened Gauge	±6mm over widened Gauge
Gauge (Maintenance) - <500m radius - S.G. Track	±6mm over widened Gauge	±6mm over widened Gauge
Gauge Face- Wear (measured 13 to 15 mm below rail top)	Straight- 6mm Curve- 8mm	Straight- 6mm Curve- 8mm

3.16 Platform Interface

3.16.1 The principal details of the Platform Interfaces are set out in Table 3.4.

Table 3.4: Platform Interfaces

Particulars		Measurements
Length of Platform (8 cars)		185 m
Width of Platform: Island type		8.0 to 12.0m
Side type		3.0 to 6.0m
Height above rail level	Ballasted Track	1080mm±5mm
	Ballastless Track (DFF)	1090mm±5mm
Floor height of the rolling stock		1130mm (max) 1100mm (min)
Distance between track centre and platform edge	At-Grade Corridor	1680 mm(max.) and 1670 mm (min.)
	Elevated Corridor	1680 mm(max.) and 1670 mm (min.)
	Underground Corridor	1670 mm (max.) and 1660 mm (min.)
Minimum horizontal curvature at platform		1000 m
Distance between track centre and platform edge on platforms at curve of 1000m	At-Grade Corridor	1700 mm(max.) and 1690 mm (min.)
	Elevated Corridor	1700 mm(max.) and 1690 mm (min.)
	Underground Corridor	1700 (max.) and 1690 (min.)

3.17 Current Collection System

3.17.1 The principal details of the Current Collection Systems are set out in Table 3.5.

Table 3.5: Current Collection System

System Particulars	For all sections and depots
Supply Voltage System	25kV AC single phase 50Hz

000389



Type of OHE	a. Auto tensioned flexible catenary for elevated and at-grade sections. b. Rigid catenary for underground sections. c. Flexible catenary for depot.
Current Collection	Through Pantograph
Height of Contact Wire from rail level	a. 4800mm min. and 5500mm max. for elevated, at-grade and depot sections. b. 4318mm min. for underground sections.
Stagger	±200mm for Rigid Catenary; ±300mm for Flexible Catenary
Nominal voltage	25.0 kV AC
Minimum voltage	19.0 kV AC
Maximum voltage	27.5 kV AC
Instantaneous minimum voltage	17.5 kV AC
Occasional maximum voltage	31.0 kV AC
Voltage for guaranteed performance	22.5 kV AC
Variation in frequency	48 to 52 Hertz

3.18 Signalling System

- 3.18.1 Principal details of the Signalling and Train Control System are set out in Table 3.6. For details see Appendix TD.

Table 3.6: Signalling System

Item	Description
Train control system	CBTC based On board Continuous Automatic Train Control system (CATC) consisting of i) Automatic Train Protection ii) Automatic Train Operation (ATO) iii) Automatic Train Super-vision (ATS) iv) Attended/Unattended train operation (GoA2/GoA3/GoA4)
Train control mode	i) Automatic mode ii) Coded Manual modes iii) Restricted Manual mode iv) Run on Sight mode v) Cut-out mode vi) UTO vii) Standby

3.19 Telecommunication System

- 3.19.1 The communications links are required to be provided, for trains on all lines, as appropriate. For full details, and division of responsibilities, see Chapter 13 and Appendix TD.

3.20 Kinematic Envelope

- 3.20.1 Kinematic Envelope on tangent level track for At-grade, Elevated sections and Underground sections have been enclosed in Appendix TE. No part of any car shall infringe the respective Kinematic Envelope, under any circumstance whether empty or fully loaded, inflated or deflated air springs on main line at all train speeds and wind speed up to 100 kmph on At-grade & Elevated corridors.

On platform, the wind speed would be taken up to 70 Kmph & train speed up to 70 kmph for At-grade & Elevated corridors.

For underground corridor, there will be no wind speed for this purpose.

Track maintenance tolerances as per clause 3.15 above will be taken into account for this purpose. Maximum allowed flange wear will also be taken into account during calculations of all car displacements resulting from the simultaneous occurrence of all above conditions.

- 3.20.2 The Contractor shall furnish a static vehicle profile of the proposed cars to suit the Kinematic Envelope under all conditions indicated in clause 3.20.1. The car body dimensions shall be optimized and maximum space should be made available for the passengers.



- 3.20.3 The Tenderer shall confirm that the kinematic envelopes as given in Appendix TE shall be respected under all conditions indicated in Clause 3.20.1.

The contractor shall furnish detailed calculations, showing lateral and vertical shifts due to each factor indicated in Clause 3.20.1 separately.

- 3.20.4 Deleted.

- 3.20.5 The Contractor, during design stage, shall submit detailed calculation for minimum clearance between the carbody exterior and platform edge keeping in mind data regarding platform interface given in Table 3.4 (para 3.16) of ERTS. The calculations shall be made for tangent track and 1000 m curved track (inside and outside platform separately) at wind speed from 30 kmph up to 100 kmph in steps of 10 kmph & vehicle speed up to 90 kmph in steps of 10 kmph under inflated and deflated springs, worn out track & wheel & taking into account maximum dynamic sway on account of clearances etc.

The Contractor shall ensure that the Train shall enter and exit the platform at the maximum speed as achievable with the specified performance parameters up to a wind speed of 70kmph with worn out track and wheels. However, for new track without considering impact of wind, there shall be no restriction to pass the platform at maximum test speed.

- 3.20.6 The Tenderer shall ensure that the cars conform to the latest version of Schedule of Dimension which shall be made available during detail design stage.

3.21 Train Performance

3.21.1 General

The following data shall be used for all normal and emergency performance requirements. The performance shall be guaranteed for traction supply voltage at 22.5 kV AC.

3.21.2 Traction Electrical Supply Systems

The maximum and minimum voltages anticipated within the traction supply systems are set out in table 3.5 above.

3.21.3 Car Weights

- (i) To minimise energy costs, great importance will be placed on achieving practical designs of minimum car weight whilst meeting specified structural and performance requirements.
- (ii) The total tare weights of a 3-Car unit (DM-T-M) shall not exceed 126 tonnes subject to gross axle load not exceeding 17 tonnes including IEC tolerances. The weight limits specified herein are the tare weight limit of the unit and gross axle load limit (tare plus AW3 load).
- (iii) The weight distribution shall be as defined in IEC 1133 - 1992.
- (iv) In case the actual weight of the train in tare condition exceeds the specified value as above, the Contractor shall be liable to pay the extra energy cost as a penalty, which shall be calculated on the basis of specified Specific Energy Consumption (SEC_s) and Achieved Specific Energy Consumption (SEC_A), whichever is higher on pro rata basis. The amount payable as penalty by the Contractor on account of increase in tare weight of the train shall be INR 15.0 Lacs/ ton per train with achieved SEC value of 47.5 Wh/GTKM (i.e. SEC_s) or less. However, if achieved SEC is higher than 47.5 Wh/GTKM then the amount payable as penalty will be increased from INR 15.0 Lacs/ ton per train on pro rata basis.

Tenderers shall note that the measured value of tare weight of train for calculation of penalty shall be rounded up to next higher integer.

For example:

If the measured value of tare weight is 253.3 ton, the value of tare weight of the train would be considered as 254 ton.

In case the tare weight of the train exceeds the specified tare weight as above, the Contractor can improve the weight of the train by making suitable hardware modifications after obtaining approval of the Engineer. The payable amount on account of excess weight shall implemented on per train basis and shall be recovered from the payable amounts under respective cost centre 'B' / 'C' (as applicable) milestones.

The total amount payable as penalty by the Contractor will be the summation of penalty amount calculated on per train basis in all such trains in which tare weight exceeds the specified tare weight.

3.21.4 Passenger Capacity

The exact number of passenger seats and standees in DM car shall be worked based on the space released due to UTO (Unmanned Train Operations viz. GoA4) and performance calculations & equipment ratings shall be optimised based on final assessment of the passenger capacity. However, notwithstanding increased number of passengers as calculated during design, energy consumption/regeneration values committed by the contractor in the contract shall not be changed and shall be considered as base values for all further evaluations.

The approximate passenger capacity for each car (in UTO mode) under seating as well as standing mode shall be as under:

	Seating	Standing		Total (Seating + Standing)	
		Fully Loaded/Dense loaded (AW3)	Crush Loading (AW2)	Fully Loaded/Dense loaded (AW3)	Crush Loading (AW2)
'DM' Car	46	334	254	380	300
'T' Car	56 (each 'T' car)	324	244	380	300
'M' Car	56 (each 'M' car)	324	244	380	300
'First Class' DM Car	64	128	96	192	160
Total	334	1758	1326	2092	1660

Note:

- The seating capacity in each car and overall total passenger capacity in a 6-car train as mentioned in Table above is the minimum number to be achieved by the Contractor.
- However, with the approval of Engineer, the total passenger capacity of any individual car may vary subjected to para (i) above in a 6-car train.
- For AW3 loading condition, the number of passengers is estimated on the basis of standees at the rate of 8 persons per square meter.
- For AW2 loading condition, the number of passengers is estimated on the basis of standees at the rate of 6 persons per square meter.
- The weight of each passenger may be taken as 65 kg.

Performance requirements with AW2 loading as above have been specified in Table 3.7. Normal Train operation shall be with AW2 loading. TE/BE curves shall be adjusted suitably with the train loading as above and shall be suitably interfaced with signaling contractor. All load dependent type tests related with the train operations, run time, schedule speed etc. as decided by the Engineer, shall be done with AW2 loading as well. Based on the final design agreed by the Engineer, the contractor shall fine tune and validate the maximum number of loading of the train for which the operational performance can be met without diluting any of the design parameters.

3.21.5 Train Resistance:



The following train resistance formulae shall be used by the Tenderer to determine train resistance and guaranteed performance for all alignments, for At-grade, Elevated and the Underground sections alongwith the bid.

For At-grade and Elevated corridors:

$$R=14.01 + 0.264V + 0.00191V^2 \text{ N/tonne}$$

For Underground Corridor:

$$R=21.96+0.4222V+0.00876V^2 \text{ N/tonne}$$

Where, V= Speed in kmph

- The curve resistance may be taken as $500/r$ kg per tonne, Where r = radius of curvature in metres.
- Starting resistance shall not be less than 5kg/ton.

The Tenderers shall use these formulae for all alignments for At-grade, Elevated corridors and Underground Corridor for giving performance details.

3.21.6 Wheel Diameters

Wheel diameter shall be taken as: -

- | | | |
|-------|------------|--------|
| (i) | New | 860 mm |
| (ii) | Half worn | 820 mm |
| (iii) | Fully worn | 780 mm |

Train performance calculations shall be based on half worn wheels except where otherwise stated.

3.21.7 Command Response Time

- Command Response Time includes response to modulation within a mode (power, coast & brake) and transition from one mode to another, including emergency brake.
- Modulation within a mode shall be jerk limited. The command response time within a mode shall not exceed 300 ms.
- Mode change dead time for transition from one to adjacent mode (motoring to coast, coast to brake, brake to coast and coast to motoring) shall not exceed 500 ms, exclusive of jerk limiting.
- The command response time shall be measured from the time the change is initiated until the acceleration or deceleration transitions to 10 percent of the requested change.

The achieved command response time as per above shall be submitted during pre-final design stage.

3.22 Performance Requirements

- 3.22.1 The Rolling stock shall be designed for safe speed of 90 kmph and operational speed of 80kmph respectively. In the interface with signaling contractor, the safe operational speed shall be considered as 90kmph, so that the maximum Target speed under ATP/ATO/UTO shall be 80kmph. Safe speed shall be considered as Rolling Stock design speed. The specified train performance shall also be achieved and validated during unattended train operations under GoA3/4 level of automation.

The performance requirements are given in Table 3.7 are with fully loaded train and tangent track

Table 3.7 Performance Requirements

Item		All Corridors
Safe speed	with inflated secondary suspension	90 kmph
	with deflated secondary suspension	80 kmph
Maximum operational speed	with inflated secondary suspension	80 kmph
	with deflated secondary suspension	70 kmph
Minimum Design Average Acceleration rate for fully loaded (AW3) train on level tangent track shall be as under: 0 kmph to 40 kmph		1.0 m/s ²

0 to 60 kmph 0 to 80 kmph	0.75 m/s ² 0.40 m/s ²
Minimum Operational Average Acceleration rate for AW2 loaded train on level tangent track shall be as under: 0 kmph to 35 kmph 0 to 60 kmph 0 to 80 kmph	1.20 m/s ² 0.80 m/s ² 0.45 m/s ²
Average Service braking rate from 80kmph to standstill for fully loaded (AW3) train on level tangent track	1.0 m/s ²
Average Service braking rate from 80kmph to standstill for AW2 train on level tangent track	1.1 m/s ²
Average Emergency braking rate from 80kmph to 0 kmph for fully loaded train on level tangent track	1.3 m/s ²
Jerk rate (Maximum)	0.75 m/s ³
Annual running distance of one train (for design purpose)	150,000 km
Note : The specified average minimum acceleration shall be the finally achieved values inclusive of the specified jerk rate. Test procedure has been specified in Chapter 15	

Contractor shall advise the minimum energy consumption mode(s) under desired headways and schedule speeds as advised to them by the Employer during the design finalization stage. The software changes for such modes shall be advised with complete details to engineer and shall be implementable by the Engineer. Subsequent to the line trials of the trains, Engineer may review the jerk rate. The Contractor shall take suitable measure to fine tune the jerk rate accordingly without any extra cost.

3.22.2 Tenderers shall indicate the total runtime and the Guaranteed "Declared Schedule Speed (DSSP)" in kmph for a round trip from, Dahisar (E) Station to Mandala Station and back (Line-2) AND Andheri (E) Station to Dahisar (E) Station and back (Line-7), under following conditions:

- (i) Train loaded : AW3
- (ii) Mode of operation : ALL OUT MODE (ATP)
- (iii) Acceleration rates : Equal to or better than the rates specified in the performance table 3.7 above
- (iv) Average service brake rate from maximum speed to standstill shall be equal to or better than the specified brake rate in the performance table 3.7 above.
- (v) Round Trip from Dahisar East station to Mandala station i.e. the travel of a 6-car train set from Dahisar East to Mandala, Turnaround at Mandala then travel from Mandala to Dahisar and again Turnaround at Dahisar East so as to reach the same point from where the journey started.
- (vi) Dwell time at each station shall be 30 secs (including door opening and closing time)
- (vii) Total Turnaround time at both Dahisar East and Mandala stations including Dwell time at both the stations shall be 6 minutes (i.e. 3 minutes at each terminal station).
- (viii) Tenderers shall indicate total time for the round trip as round trip time i.e. RTT_{DSSP}.
- (ix) Round trip time, dwell time and turnaround time for line 7 i.e. Andheri (E) Station to Dahisar (E) Station shall be considered in similar manner as specified in para (v) to (vii) above.

3.22.3 The Tenderers shall note that with AW2 loading the acceleration rates shall be suitably improved so as to achieve DSSP but with coasting of minimum 8% of the runtime (as defined in clause 3.22.2 above) i.e. the total time taken for a round trip minus the cumulative dwell time and reversal time.

Tenderers shall note that acceleration rates shall in any case be not less than the values specified in the performance table 3.7 above.



Tenderers shall furnish the considered acceleration rates for AW2 loading to achieve the above performance criteria.

3.22.4 Whenever the passenger loading is less than AW2, a load signal should be given to the traction system which should correspondingly reduce initial tractive effort and the constant power mode such that the running time between stations remain nearly the same i.e. the achieved schedule speed shall be same as the DSSP irrespective of the load on the train.

In this condition, the coasting time w.r.t. AW2 loading condition shall either increase or remain same and acceleration rate shall remain same from AW2 to AW0 loading conditions and shall be finalized during design stage.

3.22.5 The trains shall operate in the following modes:

(a) Normal (Coasting Mode) Mode:

- Accelerate the train using the designed and load weighed speed-TE characteristic of the rolling stock.
- Coast to achieve the Declared Schedule Speed(DSSP) which shall be the scheduled speed as per clause 3.22.2 above. The coasting time shall be equal to or more than 8% of the run time. Achieve rate of deceleration of not less than the values mentioned in Table 3.7 from at least 75 kmph running speed till 5 kmph with dynamic brake only and with blended brake from 5 kmph till the train comes to a stop. Full Service Brake requirements for speed range of 5 kmph to 75 kmph with load not exceeding AW2 shall be met with regeneration brakes only i.e. without any friction brake. The Regenerative braking power shall be constant from 80 kmph to 75 kmph. The regenerative power shall be used to the maximum extent possible. Deceleration for crush load shall be as specified in Table 3.7 above.
- The above steps should be taken in a manner such that scheduled speed is maximised and energy consumption is minimised. The DSSP are to be achieved with a dwell time as mentioned in ERTS 3.22.2 above at each station.

(b) All-out Mode:

This will mean maximum acceleration and deceleration with no coasting till maximum speed is achieved and thereafter speed is maintained within 5 kmph below than the maximum speed. During braking, maximum regenerative braking shall be utilised to achieve the specified retardation rate from top speed till train stops and the Jerk rate shall be limited within the specified limit.

(c) The Control system shall be such that the train will achieve the Declared Schedule Speed (DSSP) at all loading conditions subject to keeping the loading of traction system within the boundary limits of the design

(d) Normal mode will be used when trains are running in time and time table can be maintained. All-out mode will be used to make up time when trains are running late.

(e) When the train is in ATO/UTO mode, the train will get appropriate commands from Signalling system.

3.22.6 The Tenderer shall submit the data of the considered acceleration rates, average service brake rate, total Run Time, total Dwell and reversal time, Total time and Schedule speeds under different loading conditions and modes of operation enumerated in the table below:

Table No. 3.8

S. No.	Load	Mode of Operation	Acceleration Rate	Average Service Brake Rate 80 to 0 kmph	Total time (secs)			Schedule Speed (kmph)
					Run Time	Dwell & Reversal	Total	
1	AW3	ALL OUT MODE (ATP)	0 – 40 kmph =					
			0 – 60 kmph =					
			0 – 80 kmph =					
			0 – 35 kmph =					



2	AW2	ALL OUT MODE (ATP)	0 – 60 kmph = 0 – 80 kmph =						
3	AW0	ALL OUT MODE (ATP)	0 – 30 kmph = 0 – 60 kmph = 0 – 80 kmph =						
4	AW3	NORMAL MODE (ATP)	0 – 40 kmph = 0 – 60 kmph = 0 – 80 kmph =						
5	AW2	NORMAL MODE (ATP)	0 – 35 kmph = 0 – 60 kmph = 0 – 80 kmph =						
6	AW0	NORMAL MODE (ATP)	0 – 30 kmph = 0 – 60 kmph = 0 – 80 kmph =						

The Tenderer shall submit in their offer the speed-time, distance- time, line current –speed/time and tractive effort & Braking effort characteristic curves of a fully loaded (AW3), AW2 and AW0 loaded train under the specified voltage and wheel conditions in all out mode and normal mode, and also with the following details:

- (i) Round Trip Schedule speeds with 30s station stops for both the lines with:
 - a) all out mode; and
 - b) Coasting Mode excluding terminal station turnaround time with fully loaded train.
- (ii) Free run up to maximum speed and then Full service brake along with associated line current at each speed (traction component & auxiliary component to be indicated).
- (iii) Inter-station running time for each corridor, each way.
- (iv) Actual schedule speed with a dwell time of 30 seconds at each station.
- (v) Energy Consumption input at Pantograph during 'Non-Braking' (Traction & Coasting)
- (vi) Energy Consumption at input of SIV (Auxiliary Converter-Inverter) during 'Non-Braking'.
- (vii) Energy Consumption at Converter-Inverter unit during 'Non-Braking'.
- (viii) Energy Consumption input at Pantograph during 'Braking'.
- (ix) Energy exported during 'Braking' at Pantograph.
- (x) Energy Consumption at SIV (Auxiliary Converter-Inverter) from Line during 'Braking'.
- (xi) Regenerated Energy for input of SIV (Auxiliary Converter-Inverter) during 'Braking'.
- (xii) Regenerated Energy at Converter-Inverter input during 'Braking'.
- (xiii) Net energy consumption at pantograph.
- (xiv) RMS current loading.
- (xv) Line current plots.

Table No. 3.9

Proforma for submission of simulation results

Line-2 (Dahisar East to Mandala)

S. No.	Station/ Section	Run Time (Sec.)					Energy Consumption (kwh)				
		P	C	B	D	T (3 to 6)	P	C	B	D	T (8 to 11)
1	2	3	4	5	6	7	8	9	10	11	12
1	Dahisar (E) to Anand Nagar										
2	At Anand Nagar				30						
3	Anand Nagar to Rushi Sankul										



4	At Rushi Sankul			30					
5	Rushi Sankul to I C Colony								
6	At I C Colony			30					
7	I C Colony to Eksar Nagar								
8	At Eksar Nagar			30					
9	Eksar Nagar to Don Bosco								
10	At Don Bosco			30					
11	Don Bosco to Shimpoli								
12	At Shimpoli			30					
13	Shimpoli to Mahavir Nagar								
14	At Mahavir Nagar			30					
15	Mahavir Nagar to Kamraj Nagar								
16	At Kamraj Nagar			30					
17	Kamraj Nagar to Charkop								
18	At Charkop			30					
19	Charkop to Malad Metro								
20	At Malad Metro			30					
21	Malad Metro to Kasturi Park								
22	At Kasturi Park			30					
23	Kasturi Park to Bangur Nagar								
24	At Bangur Nagar			30					
25	Bangur Nagar to Goregaon Metro								
26	At Goregaon Metro			30					
27	Goregaon Metro to Adarsha Nagar								
28	At Adarsha Nagar			30					
29	Adarsha Nagar to Shastri Nagar								
30	At Shastri Nagar			30					
31	Shastri Nagar to DN Nagar								
32	At DN Nagar			30					
33	DN Nagar to ESIC Nagar								
34	At ESIC Nagar			30					
35	ESIC Nagar to Prem Nagar								
36	At Prem Nagar			30					
37	Prem Nagar to Indira Nagar								
38	At Indira Nagar			30					
39	Indira Nagar to Nanavati Nagar								
40	At Nanavati Nagar			30					
41	Nanavati Nagar to Khira Nagar								
42	At Khira Nagar			30					
43	Khira Nagar to Saraswat Nagar								
44	At Saraswat Nagar			30					
45	Saraswat Nagar to National College								
46	At National College			30					
47	National College to Bandra Metro								
48	At Bandra Metro			30					
49	Bandra Metro to MMRDA Office								
50	At MMRDA Office			30					
51	MMRDA Office to Income Tax Colony								
52	At Income Tax Colony			30					
53	Income Tax Colony to ILFS								
54	At ILFS			30					
55	ILFS to MTNL Metro								
56	At MTNL Metro			30					
57	MTNL Metro to S G Barve Marg								
58	At S G Barve Marg			30					
59	S G Barve Marg to Kurla Terminal								
60	At Kurla Terminal			30					
61	Kurla Terminal to Kurla (E)								

working, thermal rating should not be exceeded for continuous working throughout the day in each Line.

- 3.22.9 The Contractor shall handover one complete set of software(s) package and associated hardware employed by him for the above studies including assessment of energy conservation modes (ERTS 3.22.1) along with the requisite documentation, during design stage to the Engineer. The software shall simulate Run Time performance of the train under varied loads, route profiles, headway, inter-station distances, train resistance, Train formation and TE/BE characteristics, evaluation of energy conservation modes etc. The software shall not be restrictive to the above and shall be for general application with provision for the Engineer to select parameters. Nominated Engineer staff shall be fully trained and made fully conversant by the contractor for this purpose. The handed over set shall be fully functional during the contract period and post warranty period & shall require no inputs or facilities whatsoever from the Employer.

The supply of above software and its training shall be a prerequisite for completion of Final Design Review.

- 3.22.10 **The present tender is for procurement of a 6 car trainset. However, the design of the rolling stock would be such that if need be in future, it shall be possible to integrate a 2 car (T+M) unit and convert it into an 8 car trainset.**

The design of 6 car train shall take in to account future addition of one T and M car (if required) and the propulsion and other equipment ratings of the T and M car shall be optimally decided to form an 8 car train (with 62.5 % powering instead of 66.7 % powering). The design details and performance parameters of 8 car train shall be submitted by the Contractor during designed stage and got approved from the Engineer.

3.23 Emergency Operating Condition

- 3.23.1 The train shall in addition to the above be capable of meeting the following criteria without any damage to equipment

- (i) One serviceable fully loaded 6-Car train with one Motor car cut out shall be capable of pushing a fully loaded defective 6-Car train without parking brakes applied, on all Lines including a section of 4% gradient up to the next station. Thereafter, the healthy train shall, after all the passengers have been detrained at the station, continue to push the defective train up to the terminal station. There shall be no equipment damage or degradation, while maintaining safe operation. Train shall be also able to start and move on a up gradient of 4% on above condition including the conditions specified in clause 3.22.7.
- (ii) A 6-Car fully loaded train shall be capable of clearing the section, with the traction motors of one 3-Car unit cut out. The temperature rise of the traction motor and equipment shall be within rating of traction motor and other equipment in the above condition.

3.24 SPECIFIC ENERGY CONSUMPTION

Tenderers shall note that 'SPECIFIC ENERGY CONSUMPTION (SEC)' to be verified in Line-2 (Dahisar East to Mandala and back) under conditions detailed hereafter in this clause shall not exceed 47.5 Wh/GTKM, referred to as SEC_s.

This Specific Energy Consumption shall be total of two components viz. SEC for a 6 car train (with HVAC switched off) i.e. 'SEC_P' value and SEC of HVAC for a 6 car train i.e. 'SEC_H' value. These two values shall be declared by the contractor (SEC_{P-declared} + SEC_{H-declared}) during pre final design stage and the same shall be validated as detailed in this clause. The total declared SEC value i.e. SEC_{declared} for a 6 car train as declared by the contractor i.e. SEC_{P-declared} + SEC_{H-declared} shall not exceed the SEC_s i.e. 47.5 Wh/GTKM as mentioned above.

Tenderers shall note that no adjustments of the 'SEC' values obtained during validation (SEC_{P-A} (Achieved value of SEC_P) and SEC_{H-A} (Achieved value of SEC_H)) will be permissible on account of any of the following:

- Increase in length of the network in Line 2 by up to 5% of the total length of the section between Dahisar East to Mandala including change in alignment.
- Increase in number of stations by 2 (two) stations in line-2 between Dahisar East station and Mandala station.

- Any changes in station locations with consequent changes in inter-station distances/rationalization of curves & gradients between Dahisar East station and Mandala station.

Tenderers shall also note that irrespective of any tolerances specified in any relevant international Standards or relevant other engineering documents of other metros or in the submitted bid documents, with respect to the measured or SEC values, no tolerance/margin shall be considered applicable in this case.

A. COMPONENTS OF SPECIFIC ENERGY CONSUMPTION (SEC):

A1 SEC for a 6 car train (with HVAC switched off) in line-2 section (Say 'SEC_p' Wh/GTKM)

The 'SEC_p' value as declared by the contractor i.e. SEC_{p-declared} shall be validated under following conditions: -

A1.1 (i) For Combined Test Bed: Round Trip Time corresponding to DSSP (RTT_{DSSP}), from Dahisar East station to Mandala station as mentioned in clause 3.22.2 shall be considered.

(ii) For Field Trial: Actual Round Trip on main line from Dahisar East station to Mandala station in ATO/UTO i.e. the travel of a 6 -car train set from Dahisar East to Mandala, Turnaround at Mandala then travel from Mandala to Dahisar and again Turnaround at Dahisar East so as to reach the same point from where the journey started.

Contractor shall note that train may be required to run for approximately 500 meters at each turnaround i.e. at Mandala and at Dahisar East. In case the actual run during turnaround is more than 500 m but the overall increase in the length of the network is within 5 % of the total length of the section, no adjustments of the SEC values shall be permissible.

A1.2 Dwell time at each intermediate station shall be 30 seconds (including door opening and closing time).

A1.3 Total Turnaround time at both Dahisar East and Mandala stations including Dwell time at both the stations shall be 6 minutes (i.e. 3 minutes at each terminal station).

A1.4 Loading conditions: (i) For Combined test bed: AW3 loading condition.

(ii) For Field Trial: 114 passengers of 65kg each per car.

A1.5 The train operation in All-Out mode shall be as per clause 3.22.5(b).

A1.6 For Combined test bed: All-Out ATP mode as per clause 3.22.2 shall be considered.

For Field Trial: All-out ATO/UTO mode (refer Clauses TD 2.2 and 2.3 of appendix TD), as decided by the Engineer during design stage shall be considered. The decision of the Engineer shall be final and binding.

A1.7 During field trials in ATO/UTO, the door opening & closing time shall be within dwell time of 30 seconds (refer A1.2 above).

A1.8 During the run and during the reversal at both Terminal stations, full auxiliary load with all auxiliaries functioning at full load at unity duty cycle shall be in operation. However, HVAC shall be switched off during this run and if more than one air compressor is installed, only one compressor shall be working.

A1.8.1 Contractor shall submit the Average Equivalent Auxiliary load in kW at pantograph level for a round trip detailed above. The declared average equivalent auxiliary load (D_{Aux}) at pantograph level shall consider the following factors:

- Operation of all auxiliary loads (including doors opening and closing at stations /terminals) as noted above
- Efficiency of auxiliary converter-inverter.
- Cable losses in the cables between Main Transformer and auxiliary converter-inverter.

