

Dubai Rail Planning & Design Guidelines

Guidelines and Design Principles for Railway Projects
undertaken by Developers in the Emirate of Dubai

Introduction

On behalf of Dubai Roads and Transport Authority, the Rail Agency is proud to have built the first Metro in the Gulf Region, opening the Red Line in 2009 and the Green Line in 2011. Setting the highest standards in public transport, the new Metro makes travelling in Dubai a pleasure, connecting people across the Emirate. The developing rail network is also key to enhancing Dubai's reputation as a commercial hub and tourist destination.

Maintaining such quality and ensuring the integration of all modes of transportation to deliver safe and smooth transport is our goal and vision. Hence, RTA is eager to establish highest technical standards and guidelines to be adopted and followed by all parties internally and externally. Such standards and guidelines are custom made to suit Dubai environment and culture to archive stat of the art rail transit systems.

At RTA we recognise the importance of establishing a Rail Planning and Design Guideline to regulate the construction of rail systems and ensure the consistency across the network.

The guideline has been designed in two parts, a mandatory volume for developers and advisory volumes for RTA projects which encompass our experiences and lessons learnt throughout the Rail Agency's journey.

Finally, I would like to thank all parties who contributed in issuing the documents and we are privileged to be part of this effort

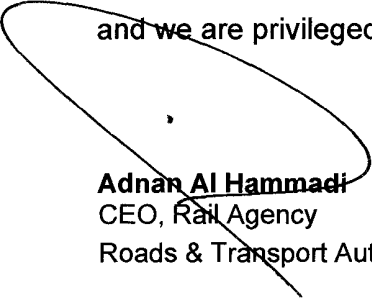

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1 Overview

1.1 Introduction

- 1.1.1.1 This document, Guidelines and Design Principles for Railway Projects undertaken by Developers in the Emirate of Dubai, referred to hereafter as the Developer Guidelines, constitutes the Railway Technical Standards referred to in Regulation No. 5 (2009) and its by-law Administrative Decision No. 68 (2010).
- 1.1.1.2 The Developer Guidelines shall be mandatory for all Dubai rail projects undertaken by external entities other than the RTA, referred to hereafter as Developers, and is intended to set out:
- a) the expectations of the RTA from designs delivered by Developers for all rail projects in Dubai;
 - b) the requirements for the preparation of submissions to the RTA, including the safety cases needed to support applications for Safety Certificates from the RTA; and
 - c) the design guidelines and principles that would help demonstrate compliance with RTA objectives.
- 1.1.1.3 The Developer Guidelines shall be the reference document for Developers and their appointed Designers, Contractors, Suppliers, Third Party Reviewers and Operators.
- 1.1.1.4 This document is structured as follows:
- a) Chapter 1- *Overview*: covers the mandatory objectives of rail transport that Developers' rail projects will have to satisfy;
 - b) Chapter 2- *Process Requirements*: covers mandatory procedures/processes that Developers need to adhere to when developing/delivering rail projects; and
 - c) Chapter 3- *Design Principles*: contains design principles that may serve as guidance for Developers, and their appointed service providers, when planning and designing rail projects and are not mandatory.
- 1.1.1.5 The objectives of this document are to promote the use of rail guided transport systems and ensure:
- a) compliance with the laws and regulations in Dubai and the UAE;
 - b) compliance with the RTA's Strategic Objectives; and
 - c) that rail systems deliver high standards of safety and performance.
- 1.1.1.6 The deliverables prepared and submitted by Developers, or their representatives, to the RTA shall demonstrate compliance with all requirements contained in this document.
- 1.1.1.7 While compliance with some of the objectives, may be subjective, the RTA will be the sole authority to determine if the spirit of compliance has been delivered.

- 1.1.1.8 The rail discipline requirements contained in this document shall cover the following modes of rail transport:
- a) Monorails;
 - b) People Movers;
 - c) Trams;
 - d) Light Rail Systems; and
 - e) Heavy Rail Systems.
- 1.1.1.9 High-speed rail and freight transport requirements are not included in this document and these may be added at a later date.
- 1.1.1.10 This document is supported at a lower level by the Rail Planning and Design Guidelines (RPDG) which can be made available as an advisory document to Developers planning on undertaking railway projects within Dubai. Compliance with the requirements in the RPDG, while optional, will ensure the issue of design phase No Objection Certificates (NOCs) and Permits and will assist with the issue of Safety Certificates by the RTA.
- 1.1.1.11 The RTA will not be liable towards Developers, or any external entity, for any issues arising from following the RPDG or any of its adopted technical standards.

1.2 Vision and strategic goals

1.2.1.1 It is important for all Developers and parties employed by them to be familiar with and comprehend the vision for, and objectives expected from, public transport in Dubai, prior to commencing design of a rail project.

1.2.1.2 Compliance with the Vision of Dubai and the RTA's Strategic Objectives is mandatory and must be demonstrated for each rail project.

1.2.2 Dubai Vision

1.2.2.1 Dubai, through the vision and initiatives of its Rulers, has rapidly emerged as a major business and financial hub and a popular tourist destination on a global level. This was made possible by the support of world class infrastructure that embodies innovation, promotes quality, advocates safety and security and upholds Dubai's unique cultural heritage. This necessitates that railway transportation, as a vital element of this supporting infrastructure, continues to be superior in terms of system safety, operational performance and level of service to meet Dubai's drive for service excellence.

1.2.3 RTA's Vision, Mission Statement and Strategic Goals

1.2.3.1 The RTA Vision is 'Safe and smooth transport for all'.

1.2.3.2 The RTA Mission Statement is 'To prepare legislation and develop integrated solutions of road systems, and land/marine transportation networks that are safe and in line with Dubai's economic development plans and the highest international standards.'

1.2.3.3 The RTA Strategic Goals and relevant Objectives are:

- a) **Goal 1: Integrated Dubai**
 - i) integrate transport planning with economic and urban planning
- b) **Goal 2: Dubai for People**
 - i) make roads and public transport more people-friendly
 - ii) preserve Dubai heritage
- c) **Goal 3: Customer First**
 - i) Improve customer service & interface
 - ii) listen to customers
- d) **Goal 4: From Cars to Public Transport**
 - i) shift demand to public transport
 - ii) Increase Bus/Metro ridership
- e) **Goal 5: Safety and Environmental Sustainability**
 - i) reduce number of accidents and fatalities
 - ii) minimise adverse environmental impact of public and private transport
 - iii) effective measures for employee health & safety sustainability

- f) **Goal 6: Financial Sustainability**
 - i) increase revenue
 - ii) increase private sector participation
 - iii) efficiently deploy financial resources
 - iv) reduce operating costs
- g) **Goal 7: Advance RTA**
 - i) develop human resources
 - ii) improve organizational efficiency
 - iii) improve systems & processes
- h) **Goal 8: Asset Sustainability**
 - i) effective and efficient AM operations
 - ii) high performing assets
 - iii) optimal asset value

1.3 Primary objectives for developers

1.3.1 Introduction

1.3.1.1 This section identifies the primary objectives that Developers have to achieve when delivering rail projects for the people of Dubai.

1.3.1.2 Compliance with these primary requirements is mandatory for all rail projects and shall be demonstrated for each rail project.

1.3.1.3 The primary objectives which Developers shall meet cover the following areas:

- a) Health and safety;
- b) Security;
- c) Passenger environment;
- d) Accessibility;
- e) Environmental sustainability;
- f) Interchange integration;
- g) Systems integration; and
- h) Transit Oriented Developments.

1.3.1.4 Designs shall be prepared to deliver rail projects to the highest level of quality, fully integrated and interoperable with existing infrastructure, with a high level of innovation in accordance with international best practice and standards.

1.3.2 Health and safety

1.3.2.1 The health and safety goal shall be to safeguard the lives of passengers, employees, contractors, vendors, emergency response personnel and the public at large when using or being associated in any way with rail transport systems in Dubai.

1.3.2.2 The strategy to achieve this goal shall include requirements:

- a) to eliminate or reduce risks to the health and safety of persons using or working on the transport system;
- b) to enable timely detection and intervention to mitigate the risks in the event of any incident;
- c) to enable timely emergency evacuation for occupants from any part of the transport system including the rolling stock in an emergency;
- d) to ensure effective access and timely emergency response to the incident scene by emergency services;
- e) to minimise property damage and the time required for operations recovery and business continuity;
- f) to protect the environment in the design, construction and maintenance of the health and safety provisions.

1.3.2.3 Ergonomics, which includes human factors, shall be recognised as a key element to design safety at every level and function of the project system lifecycle.

1.3.3 Security

1.3.3.1 The security goal is twofold:

- a) to safeguard the lives of passengers, employees, contractors, vendors, emergency response personnel and the public at large when using or being associated in any way with rail transport systems in Dubai; and
- b) to protect the assets of the rail transport system.

1.3.3.2 The strategy to achieve these goals shall include requirements to:

- a) eliminate or reduce security risks to the safety of persons using or working on the transport system;
- b) eliminate or reduce security risks to the damage of assets;
- c) enable timely detection and intervention to mitigate the risks in the event of any incident;
- d) ensure effective access and timely emergency response to the incident scene by emergency services;
- e) minimise the time required for operations recovery and business continuity; and
- f) protect the environment in the design, construction and maintenance of the security provisions.

1.3.4 Passenger Environment

1.3.4.1 The rail project shall aim to deliver high quality passenger environments that:

- a) respect social conventions and cultural norms;
- b) ensure passengers' comfortable, smooth and quick circulation;
- c) provide adequate signage and wayfinding;
- d) provide clean and hygienic facilities and amenities;
- e) provide user-friendly and automated services;
- f) create a sense of personal safety and security;
- a) allow safe and smooth integration with other forms of public transport, particularly public transport, to enhance passenger convenience; and
- b) offer a level of service that encourages the use of rail transport and increases rail transport patronage.

1.3.4.2 Free movement shall be allowed to and through stations during peak commuter periods and stations shall be able to cope adequately with flow during special events. The route to a destination shall be easily identifiable within and between stations.

1.3.4.3 A Fruin Level of Service of "C" or better shall be provided in all public areas.

1.3.4.4 Stations shall be integrated within their urban context and be easily accessible for pedestrians in addition to cyclists and other road users.

1.3.4.5 Park and Ride facilities, where appropriate, shall be encouraged by station connectivity to high quality parking facilities.

1.3.5 Accessibility

1.3.5.1 The rail transport facilities shall comply with the RTA's Guidelines for Accessible Transport in the Emirate of Dubai and cater to People with Special Needs (PSN).

1.3.5.2 The design shall adopt the following design principles:

- a) step-free access shall be provided between street and platforms/train carriages;
- c) all facilities, such as lifts, shall be located next to normal circulation areas to ensure inclusivity and prevent isolation;
- b) provision of help points at strategic locations;
- c) provision of continuous tactile paving; and
- d) PSN-friendly amenities such as ticket counters, lifts, help points, AFC and ticket vending machine controls.

1.3.5.3 The design shall address the specific needs of the following user profiles:

- a) wheelchair users;
- b) visually and hearing impaired;
- c) elderly;
- d) passengers with children, including those in prams and push chairs; and
- e) passengers with luggage.

1.3.6 Environmental sustainability

1.3.6.1 Rail projects shall aim to deliver rail transport with the minimum impact on the environment by achieving the following:

- a) use of low energy construction materials and low impact construction techniques;
- e) state-of-the-art building systems that minimize the amount of energy and water required during manufacture, installation and operation;
- f) minimum use of energy and water required for climate control, while maintaining passenger comfort; and
- g) encouraging the use of innovative insulation materials, and plant and building management systems.

1.3.6.2 Rail projects shall meet the environmental requirements of section 2.4 in this document.

1.3.7 Interchange integration

1.3.7.1 In optimising passenger safety and convenience, station planning shall facilitate quick and easy interchange between different lines and transport modes, including as a minimum:

- a) rail services;
- b) public and private buses;
- c) taxis;
- d) private cars; and
- e) bicycles and motorcycles.

1.3.7.2 Interchange routes shall:

- a) be as direct and intuitive as possible in order to minimise travel distances for the largest number of passengers;
- b) minimise changes of level; and
- c) avoid crossing gate lines.

1.3.7.3 Where Developer and RTA buildings are physically linked for passenger interchange, the following shall apply:

- a) compliance with the RTA signage manual as applicable;
- b) system links between fire alarm systems to ensure that both parties are aware of a fire threat in either building;
- c) system links between Public Address (PA) systems for co-ordinated emergency evacuation messages;
- d) system links between Closed Circuit Television (CCTV) systems to ensure that common areas and other key locations can be seen by staff in both buildings and their respective control centres;
- e) system links between radio systems to ensure that staff and emergency services can communicate seamlessly when moving between buildings;
- f) system links between Passenger Information Display (PID) systems to ensure that operational messages from one service provider may be displayed in areas managed by the other service provider – particularly for instances when the passenger interchange must be suspended or service disruptions occur for any reason; and
- g) requirements for physical interfaces at facility perimeters including security, access, maintenance, airflow, fire compartmentation, noise and light pollution, etc., shall be coordinated.

1.3.7.4 To promote passenger convenience across Dubai, compatibility with RTA's existing unified automatic fare collection (UAFC) system shall be required to permit the use of all connecting public transport services with a single common ticket (smart card).

1.3.7.5 PID systems are preferred to be consistent with RTA's existing systems in terms of passenger information format and content in order to maintain quality of service across all stations and ensure passenger convenience through provision of real-time passenger information.

1.3.8 Systems integration

1.3.8.1 This document has been produced for standalone rail systems, however, if privately developed railways will share RTA-owned and operated track then this will be subject to detailed specification to ensure the safe and reliable operation of all services.

1.3.8.2 Areas of integration shall mainly include, but not be limited to:

- a) uniformity of signalling and communication systems across Dubai's rail network to ensure safety and optimal operational performance. Use of TETRA radio systems (as provided by Nedaa) will be required;
- b) electromagnetic compatibility (encompassing earthing, bonding, lightning protection and stray current) to ensure that equipment items or systems will not interfere with or prevent each other's correct operation through spurious emission and absorption of EMI- refer to sections 2.5 and 3.4 and in appendix 1 for more details; and
- c) rail/wheel compatibility of rolling stock supplied by Developers with RTA's existing railway tracks.

1.3.9 Transit Oriented Developments

1.3.9.1 The RTA encourages transit oriented developments (TODs). TODs are generally characterized by high-quality pedestrian environments surrounding a transit station, includes a range of residential and commercial mixed land uses and features greater development density that supports public transport ridership and potentially generates higher fare revenues.

1.3.9.2 TODs shall seek to achieve the following:

- a) integrate land use and public transportation to enhance passenger/pedestrian convenience and to consequently improve ridership and ultimately boost property value;
- b) develop urban planning and design solutions that promote a sense of place/community and are responsive to the geographic and social context;
- c) address market demand and achieve the best return on investment by careful consideration of development mix and commercial opportunities that would sustain the development;
- d) promote good intermodal connectivity and provide safe pedestrian accessibility within the plot and appropriate links to adjacent environments;
- e) create or maintain public realm areas and green, open, breathing spaces within the development; and
- f) develop competent and sustainable urban forms inspired by and complementary to the local context.

1.4 Presentation and terminology

1.4.1 Use of language

- 1.4.1.1 Project documentation shall be written in a simple, clear and concise manner.
- 1.4.1.2 Project documentation shall be written in English, although other languages may also be permitted for operational purposes.

1.4.2 Document and asset identification

- 1.4.2.1 All Project documentation shall be presented in a consistent style and a document and asset identification system shall be implemented.
- 1.4.2.2 This system shall address the identification requirements for all design documentation including plans, reports, specifications and drawings and the identification of assets.
- 1.4.2.3 Version control of documentation shall be ensured through a documented change control process.

1.4.3 Consistency of terminology

- 1.4.3.1 All Project documentation including plans, reports, specifications, manuals and drawings shall utilise consistent terminology in accordance with that used by the RTA.
- 1.4.3.2 A Project Glossary shall be adopted, developed and maintained throughout the whole of the Project to include abbreviations and definitions that are necessary to support the Project and shall be attached with deliverables as relevant.

1.4.4 CAD standards

- 1.4.4.1 Wherever possible, drawings shall comply with RTA CAD standard requirements.
- 1.4.4.2 SI units shall be used throughout all aspects of the Works.

2 Process requirements

2.1 Introduction

- 2.1.1.1 This chapter presents the processes that need to be complied with to enable the RTA to issue the relevant No Objection Certificates (NOCs), Permits and Safety Certificates.
- 2.1.1.2 Adherence to these processes and procedures by the Developer and its appointed Designer/ Contractor / Operator is mandatory to demonstrate that the rail project delivery (from design to commercial operation) has been carried out in accordance with RTA's safety and operational performance requirements.

2.2 Approval and certification process

2.2.1 The railway project development process

- 2.2.1.1 A typical development process for railway projects, or any dedicated guideway system, is described in (Figure 2-1) below.

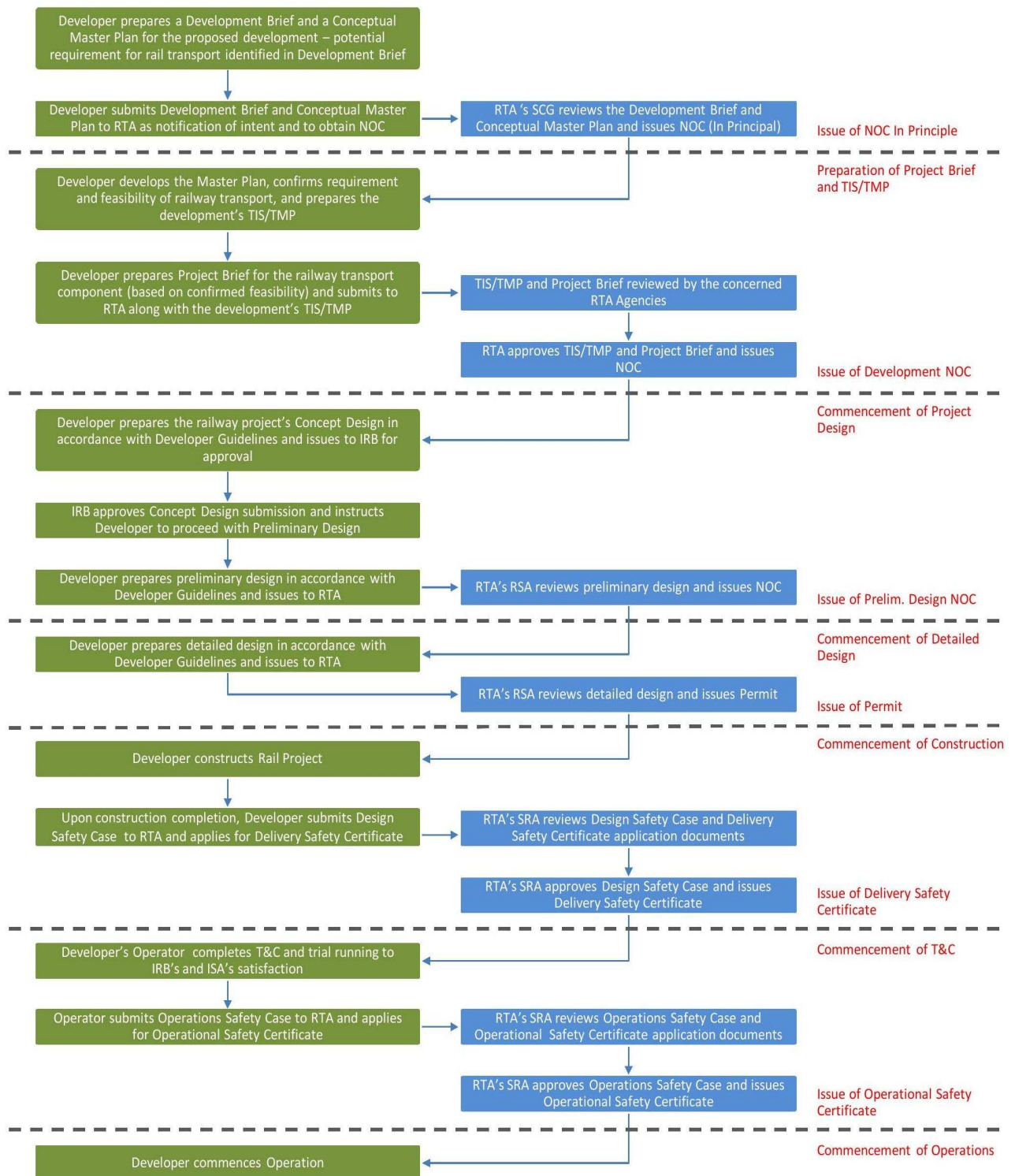


Figure 2-2: Development process for railway projects

2.2.2 Developer responsibilities during the Rail Project Development Process

Pre-design phase

- 2.2.2.1 For proposed developments that may potentially feature a rail transport component, the Developer shall submit a Conceptual Master Plan and a Development Brief to RTA's Customer Service Department as part of an application for RTA's NOC.

- 2.2.2.2 The Development Brief shall clearly identify the potential requirement for rail transport and the premise upon which this requirement is based.
- 2.2.2.3 Once the Conceptual Master Plan and Development Brief have been reviewed and approved, the RTA will issue a No Objection Certificate (NOC) In Principle to the Developer.
- 2.2.2.4 The Developer shall then develop the Urban Master Plan, confirm the requirement for public transport, undertake a Feasibility Study to confirm the rail transportation mode required, prepare the development's Traffic Impact Study (TIS) and finalise the Transportation Master Plan (TMP).
- 2.2.2.5 Any cost-sharing arrangements and agreements relating to the proposed rail transport project, whether with the RTA or any other entity, should be finalised by the Developer and accounted for prior to the completion of the Feasibility Study.
- 2.2.2.6 After confirming feasibility of the proposed rail transport project (referred to hereafter as the Project) the Developer shall produce a Project Brief for the same and issue it to the RTA, along with the proposed development's TIS/TMP, as notification of the Developer's intent and commitment to undertake the Project.
- 2.2.2.7 The Project Brief shall describe the scope and extent of the proposed railway project (not the development as this would have been covered in the Development Brief above) and shall include but will not be limited to the following:
- a) Project background, purpose and scope;
 - b) Project benefits (economic, social, environmental, etc.);
 - c) proposed phasing strategy;
 - d) funding strategy and any cost-sharing arrangements made;
 - e) milestone schedule and timeframe for Project completion;
 - f) illustrations of rail network proposed along with location of key Project elements and indication of what is underground, elevated or at grade, in accordance with the TMP;
 - g) rail transport modes considered and justification for preferred option;
 - h) service information including patronage forecasts, capacities of rail facilities, train speeds, etc.;
 - i) station planning information and artist's impressions, if available;
 - j) description of existing conditions including geotechnical investigations;
 - k) potential impacts of the Project, which may include:
 - i) physical impact on the built environment in terms of any required demolitions, utility relocations, road network reconfiguration, etc.- any impact on planned or existing RTA assets or infrastructure (including road networks and rail corridors) shall be highlighted;
 - ii) environmental impact in terms of air quality, vibration and noise levels generated during and post construction, water quality, biodiversity, etc.;

iii) socio-economic impacts in terms of community demographics, land use, public services requirements, etc.

l) projected power demands, water supply demands, including treated sewage effluent (TSE) for irrigation, and estimated drainage requirements; and

m) outcomes of stakeholder consultation.

2.2.2.8 Upon review of the Developer's Project Brief, the RTA may request additional information or clarification which the Developer shall address and provide in a timely manner to the satisfaction of RTA.

2.2.2.9 Once the RTA is satisfied with the Developer's provided information the Developer shall be notified via an NOC that the RTA has no objection towards the Developer's proposed railway plans.

Design phase

2.2.2.10 With the Project Brief reviewed and a development NOC issued by the RTA to the Developer, the Developer shall then appoint an RTA-prequalified Designer to prepare the Concept Design for the Project – refer to RTA's Prequalification Procedure and Requirements for further information on RTA requirements.

2.2.2.11 It shall be the Developer's responsibility to ensure that any entity appointed to undertake rail project-related works (whether studies, design, construction, etc.) are recognised by the RTA and are in possession of an RTA Prequalification No Objection Certificate and are licensed by Dubai Municipality. Failure to procure the services of RTA-prequalified rail service providers is illegal and will result in RTA's rejection of submitted deliverables or completed works.

2.2.2.12 The Developer shall also appoint an RTA-prequalified third party reviewer (referred to hereafter as the Independent Review Body or IRB) to check and verify on behalf of the RTA that the appointed Designer's/ Contractor's work and deliverables are in compliance with the Project Brief and Project Information (as previously submitted to the RTA), the RTA's requirements for rail transport projects as contained in this document, and in line with the relevant local governing laws and regulations.

2.2.2.13 The scope of work and contract terms of the IRB shall be approved by the RTA to ensure that it is able to discharge its responsibilities, and the appointment of the IRB will be approved by the RTA to ensure that the organisation chosen has the necessary skills and experience to perform the role.

2.2.2.14 The Developer may also consider appointing at this stage an RTA-prequalified Operator to oversee design development and ensure that designs are capable of meeting the specified operational requirements and service levels.

2.2.2.15 The Developer shall develop all stages of design (Concept, Preliminary and Detailed) in accordance with this document and any additional input provided by the RTA.

2.2.2.16 Once the Concept Design for the proposed rail project is complete the Developer shall submit the same to the IRB for review. Once deemed compliant, the IRB shall formally instruct the Developer to develop the design to Preliminary Design level.

- 2.2.2.17 The submission process described above shall be repeated for the Preliminary Design and the Detailed Design submissions, however, this time RTA approval will be required in order for the Developer to proceed to the next stage. The IRB will forward these submissions to the RTA.
- 2.2.2.18 RTA fees shall apply for review of Preliminary Design and Detailed Design submissions and the Developer shall ensure the timely payment of these fees so as not to delay the design review and approval process.
- 2.2.2.19 Upon review of the Preliminary Design submission and if deemed compliant by the IRB and if the RTA has no objections on the same then the RTA will issue a Preliminary Design NOC to enable the Developer to proceed with Detailed (Final) Design.
- 2.2.2.20 In cases where the IRB and/or RTA have comments on a submission that they deem as minor and that are easy for the Developer's Designer to address in a subsequent design approval submission then an NOC with Comments may be issued by the RTA.
- 2.2.2.21 If the project is to be delivered as Design-Build then the Developer shall ensure that the appointed RTA-prequalified Contractor procures the services of an RTA-prequalified designer as well.
- 2.2.2.22 At the completion of the Detailed Design stage the Developer shall submit the final design deliverables for approval and shall apply for RTA's Permit to commence construction.
- 2.2.2.23 Upon approval of the Detailed Design submission the RTA's Rail Supervisory Authority (RSA) will issue a Permit to the Developer to enable the start of construction.
- 2.2.2.24 In instances where the Developer wishes to start site enabling works (such as perimeter fencing, site access routes, ground preparation, safety signage, etc.) or early construction works (such as excavation, reclamation, levelling, shoring, piling, etc.), prior to completion of the project's Detailed Design then the Developer shall as a minimum submit the related detailed design documents (drawings, schedules, calculations, etc.) for these works to the RSA and apply for an 'early works' Permit.
- 2.2.2.25 For large or complex rail projects where project components are to be delivered at different phases, the Developer shall complete the Detailed Design for any component it wishes to construct prior to applying for RTA's Permit. It shall also be the Developer's responsibility to highlight any potential constraints to the construction of future components that are to be delivered in subsequent phases and demonstrate that the appropriate mitigation measures are in place.
- 2.2.2.26 Permits will not be issued for any Project component if the Developer fails to demonstrate that delivery of this component would not adversely impact the delivery of future project components.
- 2.2.2.27 To enable construction monitoring and progress updating, the RSA may request additional information from the Developer pertaining to the Project's phasing strategy, delivery schedule and components to be built. The Developer shall furnish such information to the RTA in a timely fashion in order to obtain the Permit.

Safety approval

- 2.2.2.28 The Developer shall comply with RTA's procedures for Safety Certification and Regulation.
- 2.2.2.29 The Developer shall be responsible for appointing an RTA-prequalified Independent Safety Assessor (ISA) to review and monitor system safety, on behalf of the RTA.
- 2.2.2.30 The scope of work and contract terms of the ISA shall be approved by the RTA to ensure that it is able to discharge its responsibilities, and the appointment of the ISA will be approved by the RTA to ensure that the organisation chosen has the necessary skills and experience to perform the role.
- 2.2.2.31 The ISA is best appointed during the design phase (preferably at Preliminary Design stage) to ensure that by the time that the Evidence of Safety documentation is formally submitted, the ISA will already have a full understanding of the Project and that any issues or concerns that it has raised will have been addressed.
- 2.2.2.32 As major construction and main systems installation are nearing completion, and once all the relevant safety documentation has been reviewed and verified by the ISA, the Developer, or its representative, shall submit to the IRB final construction documents (including safety-related documents previously approved by the ISA) and inspection requests for completed works.
- 2.2.2.33 Once inspections have been conducted and documents have been reviewed and both have been deemed acceptable by the IRB, the Developer, or its Contractor, shall submit the Design Safety Case to the RTA and apply for a Delivery Safety Certificate.
- 2.2.2.34 Subject to the RTA's satisfaction with the submitted Design Safety Case and all the supporting safety-related documents (which have been previously reviewed and accepted by the ISA), the RTA's Safety Regulation Authority (SRA) will issue a Delivery Safety Certificate to the Developer.
- 2.2.2.35 When testing and commissioning and trial running have been successfully completed, the Operator shall develop and submit an Operations Safety Case. This will be submitted to the SRA with an application for an Operational Safety Certificate.
- 2.2.2.36 The SRA will review the application, along with supporting evidence and, when satisfied, will issue an Operational Safety Certificate to the Operator.
- 2.2.2.37 Upon receipt of the Operational Safety Certificate, the Operator is able to commence operations of the rail facilities.

2.2.3 Submission / review process

Submission schedule

- 2.2.3.1 A submission schedule shall be used to track all project documentation as specified herein.
- 2.2.3.2 This submission schedule shall list, without limitation, all management plans, designs, drawings, construction and installation documentation, test procedures, test reports, manuals, system assurance supporting documents and all other documents required to be prepared in connection with the Project and shall:

- a) identify each item with a title that clearly indicates the nature of the submission;
- b) identify each item which is defined as being safety critical such that it is readily distinguishable from other submissions;
- c) group submissions according to the disciplines that shall generate the submissions (such as structural, geotechnical, mechanical, electrical and interior fittings etc);
- d) order submissions within each group into chronological order by type of document;
- e) provide anticipated dates for submission of each item to the RTA;
- f) provide an indication of the period within which RTA should be required to respond to each item submitted;
- g) provide columns for actual dates of submission and for references to related correspondence with the RTA; and
- h) provide a column for the status of each submission.

Issue of submissions

- 2.2.3.3 All submissions leading up to the issuing of the Delivery Safety Certificate shall be made to the IRB and these shall be forwarded to the RTA and ISA as appropriate. Submissions by the Operator will be made directly to the RTA's Safety Regulation Authority (SRA).
- 2.2.3.4 All submissions shall be provided in soft copy format. Submissions of hard copies shall be subject to IRB and/or RTA requirements.

Reviews by the IRB, ISA and RTA

- 2.2.3.5 A flowchart of the submission and review process is shown in Figure 2-2 below.

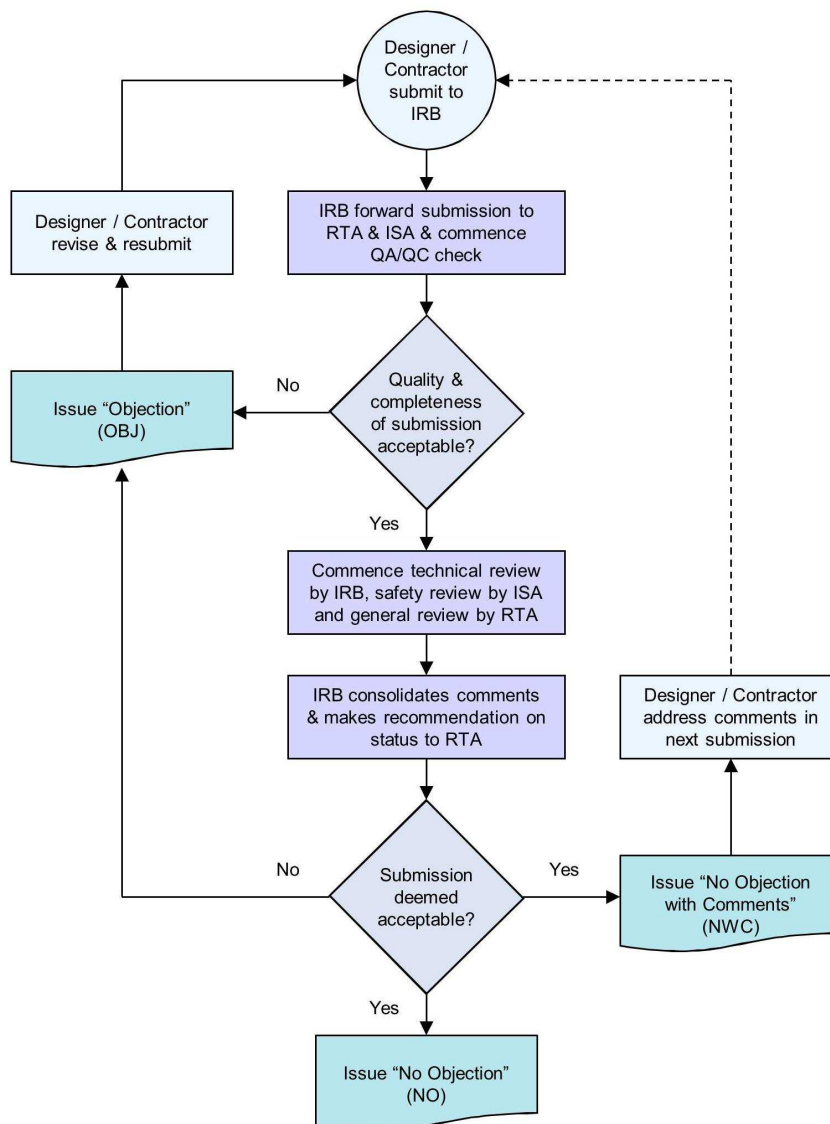


Figure 2-3: Design submission review process

- 2.2.3.6 The IRB shall perform the lead coordination role during the submission review process, conduct thorough technical reviews of all submitted documents and provide formal notification of the status of each submitted document to the RTA and, where required, the ISA.
- 2.2.3.7 RTA engineers and architects shall perform a review of matters within their discipline and not an in-depth review of every document. This optimizes RTA efforts and reduces the amount of overlap and repeated comments.
- 2.2.3.8 The ISA shall conduct reviews on submissions related to aspects of system safety and shall submit its reviews and comments to the IRB and RTA.
- 2.2.3.9 In the case of resubmissions, reviewers will only comment on changes made in response to comments or additional content, and shall not generate new comments on previously submitted content.
- 2.2.3.10 Following review, the IRB shall collate and consolidate feedback received from all reviewing parties and forward to the RTA the status of each document along with its own comments

and observations justifying the status. The RTA will review the same and in turn issue one of the following for the final deliverable of the Project:

- a) No Objection (NO), or
- b) No Objection with Comments (NWC), or
- c) Objection (OBJ).

2.2.3.11 Regardless of the status of a submission or response issued by the RTA, it shall not in any way limit the requirement of the Developer to comply with the requirements of this document.

2.2.4 Safety certification

Introduction

2.2.4.1 Before any railway Project can be put into service, the RTA needs to issue:

- a) a Delivery Safety Certificate to the Developer confirming that the completed railway infrastructure and/or railway vehicles are safe based on evidence of safety; and
- b) an Operational Safety Certificate to the Operator permitting the Operator to begin commercial operation based on evidence of safety.

2.2.4.2 An Independent Safety Assessor (ISA) will be appointed to review and monitor, on behalf of the RTA, system safety through the design, construction, testing and commissioning phases of the Project.

2.2.4.3 The principle of appointing the ISA early is to ensure that concerns raised by the ISA can be addressed in the design while it is still cost-effective to do so and to avoid disruption to the project schedule.

2.2.4.4 Any comments or queries raised by the ISA will be passed to the IRB for transmission to the Designer/Contractor, and copied to the RTA.

2.2.4.5 The RTA will take into account the ISA's recommendations when considering an application for a Delivery Safety Case.

2.2.4.6 The issuance of a Delivery Safety Certificate or Operational Safety Certificate by the RTA to the Developer or Operator will not limit the liability of the Developer for ensuring that the Project complies with the requirements of the Project Brief and this document.

Developer responsibilities to the ISA

2.2.4.7 The Developer shall take appropriate action and provide responses to all reasonable queries and comments raised by the ISA, with the ultimate aim of ensuring smooth achievement of safety certification of the Project upon submission of the Evidence of Safety.

2.3 System assurance

2.3.1 General

2.3.1.1 Systems assurance activities shall be applied throughout the design, procurement, manufacture, construction, installation, onsite testing, integrated system testing, trial running and RAM demonstration stages of the Works.

2.3.1.2 Where the Project is to be commissioned in phases, the system assurance process shall be implemented in full for the first phase. All system assurance documentation delivered for the first phase shall be updated to include subsequent phases, before each subsequent phase is commissioned.

Reference standards

2.3.1.3 System assurance activities shall comply with the requirements of CENELEC EN 50126 - Railway Applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) or the equivalent IEC 62278 standards.

2.3.1.4 System assurance activities related specifically to communications, signalling and processing systems shall comply with the requirements of:

- a) CENELEC EN 50128 - Railway Applications – Communications, signalling and processing systems – Software for railway control & protection systems; and
- b) CENELEC EN 50129 - Railway Applications – Communications, signalling and processing systems - electronic systems for signalling or the equivalent IEC 62279 and IEC 62280 standards.

2.3.2 Overview of systems assurance

2.3.2.1 System assurance activities shall be undertaken throughout the whole course of the Project in order to demonstrate in a logical, progressive and traceable manner that:

- a) the requirements of the Project Brief and the objectives of the RTA have been satisfied;
- b) the work has been executed by suitably competent people;
- c) the designs have been verified by the competent authorities;
- d) any manufacturing, construction, installation, testing and commissioning works associated with the Project have been validated;
- e) safety related aspects of the Project have been identified, analysed and mitigated such that residual risks have been demonstrated to be as low as reasonably practicable for all Project stages; and
- f) RAMS requirements of the Project have been identified, apportioned to various systems, subsystems and elements of the works and the associated designs for these have been demonstrated to be capable of meeting their allocated performance targets.

- 2.3.2.2 System assurance activities shall apply to software design as well as hardware and hardware application designs.
- 2.3.2.3 System assurance shall be applied to the integration of the Works with any existing system as required and the implications of interfacing with any such existing system shall be considered in all Design Safety Studies and other system assurance related documentation.
- 2.3.2.4 All system assurance documentation, software and procedures that are necessary for the Operator to continue the process of managing system assurance during the Commercial Operation of the Project shall be provided prior to commencement of trial running.

System Assurance Plan

- 2.3.2.5 Prior to the submission of any designs, a System Assurance Plan that describes the organisation, resources and procedures that will be established to manage system assurance activities, shall be prepared and submitted to the IRB for review- the role of the IRB is explained in section 2.2 above.
- 2.3.2.6 The System Assurance Plan shall be maintained as a live document and updated as necessary throughout the duration of the Project.
- 2.3.2.7 The System Assurance Plan shall address:
- a) the scope and purpose of the Project as defined in the Project Brief;
 - b) interfaces within the Works comprising all Architectural, Civil Infrastructure, Rail Systems and Building Services elements included within the scope of the Project as defined in the Project Brief;
 - c) interfaces to any existing system or works provided by Other Contractors, relevant authorities and third parties;
 - d) design and interface management requirements;
 - e) testing and commissioning requirements;
 - f) preparation of operations, maintenance and training documentation requirements; and
 - g) evidence of safety procedures.
- 2.3.2.8 The System Assurance Plan shall include, but not be limited to, the following subjects:
- a) the scope and purpose of Compliance Management;
 - b) the scope and purpose of Verification;
 - c) the scope and purpose of the System Safety Management;
 - d) the scope and purpose of the System Reliability, Availability and Maintainability (RAM) Management;
 - e) the method of integrating the above five activities together;
 - f) a summary of all system assurance procedures proposed for the Project including those that may differ from, or complement, those described in this document;
 - g) proposals for internal and subcontractor system assurance audits;
 - h) proposals for the preparation, collation and submission of evidence of safety documentation; and

- i) a detailed organisation chart specific to the Project identifying the responsibilities, authority and interrelation of all personnel who manage, perform and verify system assurance activities.

2.3.2.9 The System Assurance Plan shall include a programme showing in detail the timing of each activity, the anticipated dates for submission of system assurance reports and documentation and the reviews to be performed.

2.3.3 Compliance management

2.3.3.1 Compliance management activities shall be undertaken to demonstrate in a logical, progressive and traceable manner that the works satisfy the requirements of the Project Brief and the RTA.

Compliance Management Plan

2.3.3.2 Prior to the commencement of design, a Compliance Management Plan shall be prepared and submitted to the IRB for review.

2.3.3.3 The Compliance Management Plan shall include, but not be limited to, the following:

- a) a detailed organisation chart specific to the Project identifying the responsibilities, authority and interrelation of all personnel involved in compliance management;
- b) a description of the compliance management tool, if any, that is proposed to be used;
- c) a description of the processes and procedures to be applied to compliance management; and
- d) a description of the selection criteria used to assert that all key people involved in carrying out the management, design, system assurance, construction and testing and commissioning of the Works are competent to perform the tasks allocated to them.

Compliance management process

2.3.3.4 A compliance management process shall be established and maintained for the duration of the Project to:

- a) import all requirements from the Project Brief, Project Information and Developer Guidelines;
- b) import design requirements and specifications from each stage of design as they are developed and assess the impact of any changes in these.
- c) provide traceability to demonstrate that high level and low level design requirements and specifications have been verified that they satisfy the requirements of the Project Brief, Project Information and Developer Guidelines;
- d) provide traceability of review comments made by IRB and the associated responses and follow up actions;
- e) provide traceability of non-conformances and follow up actions required to address them;

- f) provide traceability of validation of testing and commissioning results against Project Brief or design requirements and specifications; and
- g) provide summary reports on key status items including, but not limited to:
 - i) Project Brief, Project Information and Developer Guidelines requirements not yet satisfied and the actions planned to address these;
 - ii) incomplete or missing verifications or validations;
 - iii) duplicated or conflicting requirements; and
 - iv) open comments from IRB.

2.3.4 Verification and validation

2.3.4.1 Verification and validation activities shall be undertaken to show in a logical, progressive and traceable manner that the:

- a) designs satisfy the requirements of the Project Brief, Project Information and the RTA; and
- b) completed works that have been subjected to testing and commissioning indeed demonstrate that they meet the requirements of the Project.

Verification and validation management plan

2.3.4.2 Prior to the commencement of design, a verification and validation management plan shall be prepared and submitted to the IRB for review.

2.3.4.3 The Verification and Validation Plan shall include, but not be limited to, the following:

- a) a detailed organisation chart specific to the Project identifying the responsibilities, authority and interrelation of all personnel involved in verification and validation;
- b) a programme of verification and validation activities that is consistent with the design programme;
- c) a description of the verification and validation processes that shall apply to the various subject areas; and
- d) a description of how the verification and validation records shall be held and tracked.

Verification and validation processes

2.3.4.4 Verification and validation shall be carried out by people who are independent from those carrying out the design.

2.3.4.5 Verification methods shall include one or more of the following:

- a) analysis of design;
- b) RAMS studies;
- c) simulations;
- d) calculations;

- e) benchmarking against international best practice where appropriate; and
- f) other methods as appropriate.

2.3.4.6 Validation methods shall include one or more of the following:

- a) review of test plans and procedures;
- b) participation in an observation and questioning role during tests;
- c) review of test results;
- d) analysis and calculations where appropriate;
- e) benchmarking against international best practice where appropriate; and
- f) other methods as appropriate.

2.3.4.7 Records of all verification and validation activities shall be kept and shall be traceable through the Compliance Management Process.

2.3.5 System safety management

2.3.5.1 System Safety Management activities shall be undertaken to demonstrate in a logical, progressive and traceable manner that the works satisfy the safety requirements of the Project Brief, Project Information and Developer Guidelines.

Safety management principles

2.3.5.2 The basic principle of safety management shall be that all reasonably foreseeable hazards are identified and action then taken for each hazard as follows:

- a) the risks arising from the hazard shall be assessed;
- b) if the risk is broadly acceptable no further action shall be required, otherwise measures shall be taken to reduce or eliminate the risk;
- c) each of these measures shall become a 'safety requirement' and all safety requirements shall be subject to verification and validation processes to show that they have been met by design and later by practical tests;
- d) the mitigation, verification and validation status of all hazards shall be recorded in the Hazard Log.

System Safety Plan

2.3.5.3 The scope and timing of all planned system safety assurance activities shall be defined in a System Safety Plan that shall cover all activities to be executed through all Project stages.

2.3.5.4 The System Safety Plan shall be developed in accordance with CENELEC EN 50126 and shall include but not be limited to the following subjects:

- a) safety policy;
- b) risk acceptance criteria;
- c) risk management;
- d) design safety studies;

- e) manufacturing, construction and installation;
- f) testing and commissioning;
- g) evidence of safety; and
- h) ongoing management of safety (during commercial operation).

Safety policy

2.3.5.5 The proposed approach and commitment to safety shall be specified in a statement of safety policy endorsed by the submitter’s senior management and this statement shall be included in the System Safety Plan.

Risk acceptance criteria

2.3.5.6 The System Safety Plan should include criteria for risk acceptance, such as those set out in EN 50126. This could include Tolerability of Risk definitions and a Risk Evaluation Matrix similar to that illustrated in (Table 2-1) below. The System Safety Plan should also include definitions for the Hazard Severity Level and Frequency of Occurrence.

Table 2-1: Example Risk Evaluation Matrix

| | | Hazard Severity level | | | |
|-------------------------|------------|-----------------------|-------------|-------------|--------------|
| | | Insignificant | Marginal | Critical | Catastrophic |
| Frequency of Occurrence | Frequent | Undesirable | Intolerable | Intolerable | Intolerable |
| | Probable | Tolerable | Undesirable | Intolerable | Intolerable |
| | Occasional | Tolerable | Undesirable | Undesirable | Intolerable |
| | Remote | Negligible | Tolerable | Undesirable | Undesirable |
| | Improbable | Negligible | Negligible | Tolerable | Tolerable |
| | Incredible | Negligible | Negligible | Negligible | Negligible |

2.3.5.7 The System Safety Plan should also explain how good practice and ‘reference systems’ will be used to demonstrate safety of specific systems, the role of Safety Targets and the use of System Integrity Levels.

Risk management

2.3.5.8 Risk management shall include those risks related to the prevention of death, injury and material loss (i.e. property and/or environmental damage).

2.3.5.9 Hazard analysis shall be carried out to:

- a) identify and record all reasonably foreseeable hazards associated with all phases of the Works;

- b) assess the risk that each hazard represents to this operation; and
 - c) re-assess the risk after application of the proposed mitigation.
- 2.3.5.10 Where it is not reasonably practical (based on good practice or application of the ALARP principle) to eliminate hazards at the design stage, risk assessments shall be carried out to ensure that the risks associated with residual hazards are in order of precedence:
- a) minimised through mitigation measures at the design stage;
 - b) mitigated through special construction, installation and testing and commissioning processes; and
 - c) mitigated through operations and maintenance procedures.
- 2.3.5.11 Additional mitigation measures shall be proposed as required until such time as the residual risk is assessed to be 'as low as reasonably practicable' as described in CENELEC EN 50126.
- 2.3.5.12 The results of the hazard analysis shall be recorded in a Hazard Log in a form that can be used to track progress in the implementation of mitigating actions and provide an easily accessible reference for the future Operator of all actions taken with respect to any hazard.
- 2.3.5.13 A Hazard Review Procedure shall be submitted to cover all the processes applicable to the development and maintenance of the Hazard Log during Commercial Operations including the process of identifying and adding a new hazard and new mitigating measures.

Primary hazards for the PHA (preliminary hazard analysis)

- 2.3.5.14 The PHA shall take into account, but not be limited to, the following primary hazards:
- a) fire including:
 - i) smoke asphyxiation;
 - ii) hot works; and
 - iii) explosion;
 - b) impact including:
 - i) collision;
 - ii) derailment;
 - iii) falling objects;
 - iv) flying objects;
 - v) sharp objects;
 - vi) slipping, tripping and falling;
 - c) electrocution;
 - d) other hazards including:
 - i) environmental;
 - ii) flooding;
 - iii) noxious fumes;

- iv) suffocation;
- v) entrapment; and
- vi) burns.

2.3.5.15 The PHA shall take into account all possible types of locations in which hazards might exist, including but not limited to:

- a) on board trains;
- b) station paid areas;
- c) station unpaid areas;
- d) station retail areas;
- e) station forecourts and street level;
- f) station non-public areas;
- g) guideways (single track, multiple track, tunnel, viaduct, elevated and at grade);
- h) evacuation routes;
- i) escape and intervention points;
- j) depot workshops;
- k) depot stabling areas;
- l) on board service vehicles;
- m) OCC; and
- n) other ancillary buildings.

2.3.5.16 The PHA shall take into account the various types of operating mode (i.e. normal, degraded and emergency) and the operating scenarios during which all types of hazards might exist including, but not limited to:

- a) passenger service;
- b) evacuation; and
- c) maintenance.

2.3.5.17 The PHA shall take into account the how each type of hazard might arise including, but not limited to:

- a) inappropriate design or specification;
- b) equipment failure;
- c) installation error;
- d) improper action (accidental or deliberate);
- e) inaction (unintentional or intentional); and
- f) external influence.

Design Safety Studies

- 2.3.5.18 Design Safety Studies shall be submitted to demonstrate that the design process incorporates the principle of minimising risk in design as a first priority.
- 2.3.5.19 Design Safety Studies shall be submitted for system and subsystem elements that are considered to be safety critical and that require hazard analysis to a greater level of detail than that applied at an overall systemwide level.
- 2.3.5.20 The hazard analysis process shall identify the need for Design Safety Studies and the Hazard Log shall record the results of each of these Design Safety Studies.
- 2.3.5.21 Design Safety Studies shall specifically refer to hazards arising from:
- a) normal operations including maintenance;
 - b) degraded modes of operation;
 - c) emergency situations; and
 - d) the effectiveness of mitigation proposed for natural catastrophes.
- 2.3.5.22 The Design Safety Studies shall take account of:
- a) methods of operation;
 - b) RAM considerations;
 - c) anticipated likely maintenance regimes and their sustainability in Commercial Operation;
 - d) anticipated competence levels of personnel in Commercial Operation;
 - e) software security (disabling of unauthorised access to operating systems, protection against intrusive attacks, loss of password integrity, etc.); and
 - f) other human factors including but not limited to those identified in ergonomic studies.
- 2.3.5.23 The format of the Design Safety Studies shall be applied consistently to all systems and subsystems.
- 2.3.5.24 A Design Safety Report shall be submitted at the completion of the design stage to confirm that all safety related aspects of design have been properly addressed and comprehensively verified.

Manufacturing, construction and installation

- 2.3.5.25 The manufacturing, construction and installation section of the System Safety Plan shall cover safety considerations for all manufacturing and installation activities and shall include, but not be limited to:
- a) identification of the safety management organisation that shall be responsible for site management, supervision and safety personnel during the manufacturing, construction and installation stages; and
 - b) the processes by which the safety impact of changes occurring during the manufacturing, construction and installation stages are assessed.

Testing and commissioning

- 2.3.5.26 The testing and commissioning section of the System Safety Plan shall include, as a minimum, commitment:
- a) that provision for a safety management organisation to control the testing and commissioning shall be in place;
 - b) that the scope of activities to be carried out during the testing and commissioning period shall cover all safety requirements including those in the Hazard Log;
 - c) that testing and commissioning activities shall be segregated from residual construction and installation activities and that procedures shall be implemented to ensure that testing and commissioning activities are carried out safely including, where necessary, protection measures for any part of the railway which may be in operation;
 - d) that processes shall be implemented to validate the safety critical aspects of software testing;
 - e) that processes shall be implemented to assess the safety implications of the results of tests and inspections carried out during the periods of testing and commissioning activities;
 - f) that all modifications carried out during the period of testing and commissioning activities shall conform to hazard identification and analysis;
 - g) that processes shall be implemented to record, report and investigate accidents and incidents together with procedures necessary to formulate and implement measures to prevent reoccurrence; and
 - h) that effective controls shall be implemented in respect of the activities of all other contractors, relevant authorities and third parties.

Evidence of safety

- 2.3.5.27 The evidence of safety requirements shall be implemented to ensure that the Works are fit for operation.
- 2.3.5.28 The evidence of safety documentation shall make traceable reference to system documentation that shall demonstrate as a minimum that:
- a) the Works have been manufactured, installed and tested (up to and including integrated system testing) in a manner to ensure that the railway can be operated and maintained within the parameters of risk as approved in the design safety report and that there are no outstanding safety issues;
 - b) the standards and specifications upon which the safe operation and maintenance of the Works are based have been specified;
 - c) safe systems of work, rules and procedures required to operate and maintain the Works within the defined parameters of risk as approved in the design safety report have been verified; and
 - d) a period of Trial Running has been completed in accordance with the testing and commissioning and evidence of safety requirements to ensure that readiness for

operation has been demonstrated and that the operator and operating procedures are fit for the purpose of commencing commercial operation.

2.3.5.29 The period of Trial Running may include the following activities:

- a) demonstration of system performance and adherence to timetables by running a simulated commercial operation at progressively increasing levels of service;
- b) evaluation of the effectiveness of normal operating procedures including those that deal with minor disruptions and staff non-availabilities;
- c) evaluation of the effectiveness of system fault reporting, fall back systems, operating procedures and maintenance responses in the event of a number of system failures and degraded operating scenarios by simulating such scenarios during simulated Commercial Operation; and
- d) evaluation of the effectiveness of operating procedures and other incident management responses in the event of a serious incident including but not limited to fire by simulating such scenarios during simulated commercial operation.

Ongoing management of safety

2.3.5.30 The System Safety Plan shall describe the process by which ongoing safety issues shall pass to the Operator to be addressed by the Operational Safety Plan.

2.3.5.31 A document covering the ongoing management of safety shall be submitted to the RTA prior to the commencement of Trial Running. This document shall meet the following requirements:

- a) it shall incorporate proposals for safety performance monitoring and safety audits throughout the Trial Running stage of the Project;
- b) it shall define the safety related documentation generated through system assurance processes and activities that shall be handed over to the Operator;
- c) it shall define the safety related procedures to be implemented during Commercial Operation including specifically the maintenance of the Hazard Log and Change Management procedures; and
- d) it shall define the safety related procedures to be implemented in the event of significant modifications to and/or extensions of the Project.

2.3.6 Reliability, availability and maintainability (RAM) management

2.3.6.1 RAM Management activities shall be undertaken in order to demonstrate in a logical, progressive and traceable manner that the works satisfy the requirements of the Project Brief and the IRB pertaining to RAM.

2.3.6.2 A System RAM Plan shall be prepared and submitted to define the scope of the RAM activities. This System RAM Plan and supporting RAM analysis shall be developed in accordance with CENELEC EN 50126.

2.3.7 System assurance support at different project stages

Design phase

2.3.7.1 Studies and other related design activities described below shall be carried out as an integral part of the overall design process.

2.3.7.2 A system shall be put in place for managing the close out of corrective actions raised during audits and to ensure that changes are fully implemented, as required.

Design safety studies

2.3.7.3 All Design Safety Studies shall be completed and the Design Safety Report submitted prior to completion of the design phase.

2.3.7.4 The findings of the Design Safety Report and outline RAM report shall be used in preparing the Detailed Design.

Ergonomic studies

2.3.7.5 Ergonomic studies shall be carried out and shall ensure that equipment and workplace designs are appropriate for the tasks allocated to users be they operations staff, maintenance staff or passengers.

2.3.7.6 Ergonomic studies shall take account of possible human errors to ensure that the design of human machine interfaces minimises the frequency and potential severity of human errors.

2.3.7.7 Ergonomic study reports shall be submitted prior to the Design Safety Study for the related equipment so that the recommendations in the ergonomic study report can be reviewed in conjunction with the Design Safety Study.

RAM analyses

2.3.7.8 RAM analyses shall be updated during the Detailed Design stage, once sub-system and component RAM information has been determined.

2.3.7.9 Projections of reliability growth shall be submitted at the Detailed Design stage.

2.3.7.10 A definitive RAM report shall be submitted at the end of the Detailed Design stage, summarising the activities that have been carried out. This report shall provide recommendations for additional RAM analysis activities to be included in later stages of the Works.

2.3.7.11 Findings of the definitive RAM report shall feed into a Maintenance Plan which shall include, but not be limited to, the following:

- a) extent and frequency of preventative maintenance actions;
- b) techniques to be employed to monitor the maintainability aspects; and
- c) a list of maintainable items or systems/subsystems that can be defined as Line Replaceable Units.

Manufacturing, construction and installation phase

2.3.7.12 Manufacture or installation shall not commence until the System Assurance Plan, System Safety Plan, System RAM Plan and Design Safety Report have been submitted and no objection has been recorded against them.

Defect reporting and corrective action system (DRACAS)

- 2.3.7.13 A Defect Reporting and Corrective Action System (DRACAS) shall be established to provide a documented history of problems and failures that occur during manufacture, construction, installation and testing and commissioning and shall be used to provide feedback to the design.
- 2.3.7.14 The DRACAS shall be used to monitor the performance of components, to indicate how and why each problem arose, to identify patterns of failures and propose options for corrective action.

Testing and commissioning phase

- 2.3.7.15 Testing and commissioning shall not commence until a Detailed Testing and Commissioning Plan has been submitted and no objection has been recorded against it in accordance with the testing and commissioning requirements.

Safety validation

- 2.3.7.16 Testing shall validate that all safety related functions have been implemented in accordance with the Detailed Design and the requirements of the Design Safety Report.
- 2.3.7.17 A programme of all safety validations to be carried out shall be submitted and this programme shall be updated with actual dates of validation during the onsite testing and integrated system testing phase.
- 2.3.7.18 Validation of the correct implementation of all safety design criteria shall be demonstrated by submitting details including:
- a) a cross reference to the programme of safety validations;
 - b) the purpose of each validation;
 - c) the method of each validation;
 - d) the qualifications of staff performing the validation;
 - e) the names of witnesses to the validation;
 - f) the acceptance criteria for each validation;
 - g) the results of each validation;
 - h) analysis of validation results to show that they confirm requirements have been met; and
 - i) the recommended procedure for the correction of deficiencies observed during the validation process and the steps required to repeat the validation.

RAM demonstrations

- 2.3.7.19 The RAM Test Plan shall describe the procedures to be carried out to monitor RAM performance during the factory testing, on site testing, integrated system testing Trial Running and RAM demonstration period.
- 2.3.7.20 Sub-contractor RAM Test Plans, if any, shall be compatible with and complement the overall RAM Test Plan.

- 2.3.7.21 The information generated during the RAM demonstrations shall be recorded and an assessment shall be made of the achieved performance compared to the RAM requirements. This assessment shall be submitted in the form of a RAM Test Report.
- 2.3.7.22 Particular emphasis shall be given to the demonstration of systems, equipment or components that are ‘new’ or ‘custom built’ and thereby have a limited history in the field.
- 2.3.7.23 Procedures incorporating proposed testing methods shall be submitted to the IRB. Testing methods shall include, but not be limited to:
 - a) environmental stress screening (pre-production) - to identify early failures due to weak parts, workmanship defects and other non-conformities; and
 - b) reliability acceptance testing (production) - to assess equipment performance.
- 2.3.7.24 Corrective action shall be implemented where the test results indicate that this shall be necessary, before commencement of Commercial Operations.

Operation phase

- 2.3.7.25 Commercial Operation shall not commence until the evidence of safety documentation has been accepted and an Operational Safety Certificate has been issued by the RTA.
- 2.3.7.26 System assurance activities shall continue during and after the transition to Commercial Operations.
- 2.3.7.27 RAM performance of the Works shall be monitored during the Defects Correction Period.
- 2.3.7.28 Full technical support in failure investigation and rectification shall be provided in the event that a failure or defect is detected during the Defects Correction Period.
- 2.3.7.29 Support shall be provided to the Operator to ensure that the documentation and processes defined in the Ongoing Management of Safety document have been fully assimilated into the Operator’s Safety Management System.

2.3.8 Systems assurance document submissions

2.3.8.1 System assurance documentation shall be submitted in accordance with the System Assurance Plan and the sub plans for Compliance, System Safety and RAM Management. The table below lists typical system assurance document submissions and the corresponding project phase at which they may be required.

Table 2-2: System assurance document submissions

| Item | Document Description |
|-----------------------------|----------------------------|
| Concept Design Stage | |
| 1 | System Assurance Plan |
| 2 | Compliance Management Plan |
| 3 | Verification Plan |
| 4 | System RAM Plan |
| 5 | System Safety Plan |
| 6 | Safety Policy |

| | |
|---------------------------------|------------------------------------|
| 7 | Hazard Analysis and Hazard Log |
| 8 | Fire Engineering Plan |
| 9 | EMC Control Plan |
| 10 | Ergonomic Study Reports |
| 11 | Design Safety Studies |
| 12 | Subsystem RAM Allocation Report |
| 13 | Compliance Report |
| Preliminary Design Stage | |
| 1 | RAM Analysis and Prediction Report |
| 2 | FMECA |
| Detailed Design Stage | |
| 1 | System Assurance Report |
| 2 | Design/System Safety Report |
| 3 | RAM Demonstration Plan |
| Testing/Trial Run Stage | |
| 1 | Hazard Review Procedure |
| 2 | Evidence of safety documentation |
| Warranty Stage | |
| 1 | RAM Demonstration Report |

2.4 Environmental sustainability and planning

2.4.1 Introduction

- 2.4.1.1 The purpose of this section is to provide the Developer with a Code of Practice to adhere to. These guidelines are based on environmental social sustainability parameters.
- 2.4.1.2 The Developer, and its appointed service providers, shall ensure that sustainability features are incorporated into the design of the Project from the outset, where feasible, and that environmental protection measures are implemented throughout the Project life cycle.
- 2.4.1.3 The Developer shall develop a specific Sustainability Awareness Strategy for the Project.
- 2.4.1.4 The Developer shall ensure that the Project addresses relevant Government policy in respect of Energy Conservation, Green Building, Sustainability and the Environment. Issues to be considered include energy and water consumption, the procurement of materials and reduction in greenhouse gas emissions.

2.4.2 Design Requirements

- 2.4.2.1 All Projects shall be designed as high-quality world class integrated systems with high-performance, energy-efficient facilities that are carefully integrated into the surrounding land use. Extensive use of energy saving and efficient systems, water efficient and recycling systems, low-embodied energy materials, and the application of renewable energy techniques shall be incorporated into the design of Projects.
- 2.4.2.2 The design shall comply with all local statutory and regulatory requirements regarding sustainable design, including but not limited to:
- a) Dubai Municipality Green Building Regulations and Specifications whose purpose is to improve the performance of buildings in the Emirate of Dubai; and
 - b) Dubai Municipality Generalization to all Consultant's Offices and General Contracting Companies Working in the Emirate of Dubai, Reference No. 812\02\1\806340 Resolution No. 161 "Concerning Implementation of Green Building Standards in Emirate of Dubai". This provides specific instruction to integrate sustainable methods and standards in the fields of energy, environment and internal air, water, lighting and control systems.
- 2.4.2.3 The Design shall comply with all Dubai Electricity and Water Authority (DEWA) and DM Regulations, particularly in the design of buildings, for electricity and water consumption.

2.4.3 Integrated Approach to Sustainability

- 2.4.3.1 Sustainability shall be applied across all aspects of a Project.
- 2.4.3.2 An Integrated Sustainability Strategy shall be prepared and submitted to the IRB for approval.
- 2.4.3.3 The Integrated Sustainability Strategy shall include; as a minimum;
- a) the team structure;

- b) stakeholder methodology for ensuring interaction;
- c) narrative summarising vision;
- d) objectives and targets; and
- e) implementation strategy for the different phases of work.

2.4.4 Sustainable practices during construction

2.4.4.1 During the construction phase of the Project, sustainable construction practices shall be applied that:

- a) employ water and energy-efficient construction methods, equipment and machinery;
- b) minimise the generation of construction waste and pollution (including noise and vibration);
- c) do not compromise the health and safety of workers and the general public; and
- d) fulfil the intent of the design.

2.4.4.2 Construction Logistics Centres (CLCs) shall be implemented, as appropriate, to support the following:

- a) manage “just in time” deliveries and optimise on-site storage space;
- b) manage and organise the sorting, storage and distribution of materials to minimise loss and damage;
- c) manage construction waste and material recycling; and
- d) manage construction traffic and operations to minimise disruptions and inconvenience to the surrounding areas.

2.4.5 Sustainable practices during operation

2.4.5.1 During the operation phase of the Project, sustainable operational practices shall be applied to:

- a) facility operations and maintenance: such as pest management, cleaning services, lighting & HVAC systems, recycling & waste disposal, staff vehicle selection, renovation & remodelling, water use, grounds maintenance and stormwater control; and
- b) office operations: such as paper use (forms, reports, etc.), selection of office supplies, equipment and appliances, operation of cafeteria and staff amenities.

2.4.6 Environmental planning requirements and legislation

2.4.6.1 All projects shall be designed, constructed and operated in accordance with the Dubai environmental regulations and shall adopt international best practice wherever practical.

Environmental regulatory process

2.4.6.2 All projects which will have a significant impact on the environment shall be assessed in accordance with the requirements of Dubai Municipality Environment Department.

2.4.6.3 For rail infrastructure projects in Dubai, an Environmental Impact Assessment (EIA) shall be produced in the form of an Environmental Impact Report (EIR).

2.4.6.4 The process commences when the Developer requests a planning permit for the Project. The Dubai Municipality Environment Department will request an EIR which will be submitted to the Environment Protection and Safety Section (EPSS) and the Dubai Municipality Planning Department for their determination. If the DM is satisfied with the EIR, a No Objection Certificate (NOC) will be issued to the Developer to allow it to commence construction.

Federal legislation

2.4.6.5 The main environmental legislation in the Emirate of Dubai is at the Federal level such as Federal Law 24 of 1999 on the Protection and Development of the Environment. There are a number of key Federal Laws which relate to rail infrastructure projects as follows:

- a) Federal Regulation for the Assessment of Environmental Effects of Installations;
- b) Federal Regulation for the Protection of Air from Pollution;
- c) Federal Regulation for Handling Hazardous Materials, Hazardous Wastes and Medical Wastes; and
- d) Federal Regulation for the Protection of the Maritime Environment.

National EIA guidelines

2.4.6.6 Environmental management in Dubai is governed by the Environmental Protection Regulations for the Emirate of Dubai (Local Order 61/1991) which is regulated by the DM. The EPSS of the DM issues technical guidelines and regulations for EIA and environmental protection as follows:

- a) DM Technical Guideline No 4 – Guidelines for Preparation of Environmental Impact Statements for Industrial Projects; and
- b) DM Technical Guideline No 53 – Environmental Impact Assessment Procedures.

2.4.6.7 Technical Guideline No. 4 states that all major projects must submit an Environmental Impact Statement (EIS) and include key information such as project description including site location and layouts, emissions to air and water, health and safety and emergency contingency plans as well as waste generated and hazardous materials consumed. Technical Guideline No. 53 describes the process for EIA and approvals in Dubai.

National environmental protection guidelines

2.4.6.8 There are a number of environmental protection regulations and guidelines which must be adhered to during the construction and operation of rail infrastructure projects as follows:

- a) Air Quality:
 - i) Chapter III of Local Order 61 / 1991 relates to air pollution from stationary sources;

- ii) DM EPSS Information Bulletin (2003) relates to allowable emission limits from stationary sources; and
 - iii) DM EPSS (2005) Ambient Air Quality Standards relates to air quality monitoring.
- b) Noise:
- i) Technical Guideline No. 44 requirements for the reduction of construction and demolition noise;
 - ii) Chapter VII (Article 75) of Local Order 61 / 1991 relates to mechanical noise; and
 - iii) Chapter VI (Article 42) of Administrative Order 211 / 91 relates to emissions from premises.
- c) Waste and Wastewater Discharges:
- i) Chapter I of Local Order 61 / 1991 relates to reuse and land disposal of wastewater and sludge;
 - ii) Chapter II of Local Order 61 / 1991 relates to disposal of wastewater into marine waters;
 - iii) Administrative Order 211 / 1991 of Local Order 61/ 1991 relates to liquid effluent standards;
 - iv) Local Order 8 / 2002 relates to disposal of untreated groundwater into storm water system;
 - v) DM EPSS Information Bulletin (2003) – relates to land contamination.

2.5 Electromagnetic compatibility and stray current protection

2.5.1 Introduction

2.5.1.1 The purpose of this section is to define the general electromagnetic compatibility and earthing, bonding, stray current and lightning protection requirements to be considered and the procedures to be followed during the design of the Works to ensure that as far as possible:

- a) the Project shall not create any electromagnetic disturbance to external parties;
- b) the Project shall not be susceptible to electromagnetic interference from external parties;
- c) the systems and subsystems forming the Project shall not create any electromagnetic disturbance to each other;
- d) electrical safety for the general public, passengers and railway staff;
- e) protection of people and railway infrastructure from lightning strikes; and
- f) ensuring that stray current on DC railways is minimised and can be remotely monitored from the OCC in order to prevent corrosion of railway infrastructure and other public and private facilities adjacent to the railway.

2.5.1.2 The electromagnetic compatibility and earthing, bonding, stray current and lightning protection requirements shall apply to the whole of the Project.

2.5.1.3 The application of these requirements to the Project shall be coordinated with all Contractors employed on the Project.

2.5.1.4 In the implementation of the electromagnetic compatibility and earthing, bonding, stray current and lightning protection policy, account has to be taken of the interrelationship of all systems comprising the Project.

2.5.1.5 Where the Project is to be commissioned in phases, the design process shall be implemented in full for the first phase. All design documentation delivered for the first phase shall be updated to include subsequent phases, before each subsequent phase is commissioned.

2.5.1.6 When applying for a Delivery Safety Certificate, the Developer's Designer / Contractor shall demonstrate that all requirements listed in clause 2.5.1.1 have been satisfied for the Project.

2.5.1.7 For particular design guidance on electromagnetic compatibility, refer to section 3.4. For further information and guidance on earthing and bonding arrangements, refer to appendix 1 of this document.

2.5.2 EMC control plan

2.5.2.1 An EMC Control Plan shall be submitted which shall provide as a minimum the following information:

- a) description of the scope of the Works;

- b) description of the environment in which the Works shall operate;
- c) definition of the persons responsible for EMC design and verification, their competency and the organisation and roles of other parties involved in these processes;
- d) description of a stakeholder management process to identify persons responsible for EMC in third party installations;
- e) identification of safety critical and performance affecting systems;
- f) identification of all deliberate transmitters from site surveys;
- g) identification of radio receivers from site surveys;
- h) identification and analysis of EMC hazards;
- i) programme of design reviews to describe how EMC shall be managed during project implementation;
- j) EMC maintenance requirements to define how EMC shall be maintained once the system is operational;
- k) identification of design standards to be applied as part of hazard mitigation;
- l) establishment of limits for emission and immunity to be applied as part of hazard mitigation;
- m) approach to ensuring compatibility between proposed EMC mitigation and the earthing, stray current and lightning protection policy and design;
- n) strategy and plan for the testing and validation processes to be implemented; and
- o) list of EMC deliverables that shall provide evidence of safety of the Works.

2.5.2.2 The EMC Control Plan shall consider all elements of the Works in the environment in which they shall operate with respect to both emissions of and susceptibility to electromagnetic interference.

2.5.2.3 The EMC Control Plan shall identify all relevant laws, regulations and relevant standards that shall be applied to the analysis and mitigation of EMC hazards.

2.5.3 Overall EMC requirements

2.5.3.1 The stakeholder management process shall identify all external elements that may act as sources of or be susceptible to electromagnetic interference and shall identify the organisation responsible for each element.

2.5.3.2 Where a risk of interference is identified, mitigation shall be proposed and implemented through an interface management process.

2.5.3.3 EMC system design documentation shall include, where appropriate:

- a) EMC modelling reports;
- b) EMC analysis reports;
- c) EMC design drawings;

- d) EMC design reviews; and
- e) the Project specific earthing and bonding design review.

- 2.5.3.4 The identification and analysis of EMC hazards shall be carried out in accordance with the system assurance procedures described in section 2.3 of this document. All proposed mitigation measures shall be closed out by reference to design standards and test results.
- 2.5.3.5 Mitigation measures shall be coordinated with the provisions for earthing, bonding, stray current and lightning protection as described herein.
- 2.5.3.6 In proposing mitigation measures for EMC hazards, electrical safety of persons shall take precedence over protection of equipment or systems.
- 2.5.3.7 Electromagnetic compatibility shall be tested wherever practicable through testing of both individual components and complete systems.
- 2.5.3.8 Where testing of complete systems is not practicable, testing of representative parts of the system shall be carried out.
- 2.5.3.9 The EMC test plan shall identify the testing required at both component and system or subsystem level.
- 2.5.3.10 Where component parts have been tested for compliance with the applicable standards for emission and susceptibility and certificates of compliance have been issued by an Independent Safety Assessor, further component testing shall not be required. All such certificates shall be submitted.
- 2.5.3.11 Integrated factory tests shall be the subject of detailed planning and coordination, with the results used for refining the on-site testing to ensure that all systems are fully integrated into the overall operating environment.
- 2.5.3.12 On-site testing shall be carried out to measure and record the performance of equipment and systems in their intended operating environment and the presence of potential electromagnetic disturbances.
- 2.5.3.13 All test results shall be submitted as part of the testing and commissioning process.

2.5.4 Testing and commissioning procedures

General

- 2.5.4.1 All installed equipment shall be tested in accordance with the procedures of the relevant EN and IEC standard. In the absence of such a standard then testing shall be done to an alternate standard acceptable to the IRB.

Site testing and commissioning

- 2.5.4.2 After installation of the equipment, tests shall include, but not be limited to, the following:
- a) visual checks for complete installation of all connections and assembled parts without any damaging, crack or scratch of wires and material, in compliance with construction drawings and required technical specifications;

- b) visual inspection of earth mat during construction to check and confirm the positioning, installation and joints;
- c) visual inspection of all cables and fire barrier to check positioning, joints (if applicable), fittings, terminations, and fixing bolts;
- d) connection check by earth insulation tester to ensure that the earthing system is perfectly connected;
- e) measurement of earthing resistance after completion of installation with acceptance standard method for main earth farms, earth grid, stray collection mat, etc., and that the earthing resistance shall not exceed the Project resistant requirement value;
- f) insulation resistance test for the earthing cable;
- g) visual and inspection of location, alignment and final installation of the running rail components;
- h) checking and measurement of the electrical rail resistance, insulation level to earth of the running rail system, including insulated rail joints; and
- i) testing of the earthing system continuity for all equipment enclosures, conduits, raceways, exposed expansion joints, lighting fixtures, receptacles, light standards, metal fencing and the like.

2.5.4.3 Ongoing monitoring and testing of stray current by the Contractor shall continue throughout the defects correction period.

2.6 Fire and life safety strategy

2.6.1 General

- 2.6.1.1 The issue of a fire safety certificate by the Dubai Civil Defence is a pre-requisite for the RTA to issue safety certificates for the provision of a public service. Documentation shall be provided and tests shall be completed by the Developer as required by the Dubai Civil Defence in order to secure the fire safety certificate.
- 2.6.1.2 The Dubai Civil Defence shall act as the Authority Having Jurisdiction (AHJ) with respect to compliance with the requirements of NFPA 130.
- 2.6.1.3 The requirements described in this section shall apply except where these are clearly inappropriate to the Works and relaxation has been granted by DCD.

2.6.2 Fire and life safety

Design codes and criteria

- 2.6.2.1 The fire and life safety design shall comply with the directives provided by:
- a) the Dubai Civil Defence in the UAE Fire and Life Safety Code of Practice, hereafter referred to as the 'Civil Defence Fire Code'; and
 - b) the local Dubai building codes, as applicable.
- 2.6.2.2 Where the UAE Fire and Life Safety Code of Practice does not apply and no specific requirements for Dubai are defined by the relevant authorities, the fire and life safety design shall be based on the requirements established in NFPA 130, together with other related NFPA standards as quoted in NFPA 130.
- 2.6.2.3 For rolling stock the fire and life safety design shall be based on the requirements of NFPA 130 or CEN/TS 45545.
- 2.6.2.4 NFPA 130 allows the use of fire engineering as an alternative to the standard requirements through:
- a) Equivalency - Nothing in this standard is intended to prevent or discourage the use of new methods, materials, or devices, provided that sufficient technical data are submitted to the AHJ to demonstrate that the new method, material, or device is equivalent to or superior to the requirements of this standard with respect to fire and life safety.
 - b) All proposals for such equivalency shall be submitted to the IRB for review and comment before they are presented to the AHJ for approval. Any No Objection response from the IRB shall always be conditional upon receipt of an approval from the AHJ.
- 2.6.2.5 The performance-based fire engineering approach to fire safety design may be adopted which relies on the use of fire engineering principles, calculations and/or appropriate software modelling tools to satisfy the intentions of the NFPA requirements. This approach provides an alternative means of meeting the intentions of the standard requirements.

Designers/practitioners therefore have the added flexibility in the application of fire safety principles to their stations by having a choice of using a performance-based approach, the NFPA standard requirements or a combination of both.

- 2.6.2.6 A fundamental aspect of the fire engineering approach shall be an assessment of actual hazards and the adoption of realistic design fires that shall form the basis of the design principles for appropriate life safety support systems.
- 2.6.2.7 Performance based fire engineering shall use risk assessment and computer modelling techniques to gain more in-depth insight and understanding of a fire and its hot combustion products on the building and its occupants. The techniques which are internationally well established and accepted include the following:
- a) risk assessment and ALARP (As Low As Reasonably Practicable): Risk assessment studies assess the building and its associated fire hazards, and what could lead to a fire occurring and its consequences. Control actions should be developed to reduce the level of risk to an 'acceptable' level. ALARP describes a risk that has been agreed to be at an acceptable level and may not require any further considerations.
 - b) computer modelling of:
 - i) Smoke movement: smoke movement can be assessed by several computer modelling techniques ranging from zone models for specific rooms, Computational Fluid Dynamics (CFD) for the complete stations to Subway Environmental Simulation (SES) for a tunnel system. The fire engineer assessing smoke movement in tunnel systems shall be competent in identifying the most appropriate modelling technique for the scenario to be modelled.
 - ii) Evacuation: evacuation modelling can be assessed by traditional hand/spread sheet calculations to more extensive computer modelling tools including EXODUS, STEPS, Pedflow and Legion. The fire engineer shall be competent in identifying the most appropriate modelling technique for the evacuation scenario to be assessed.
 - iii) Structural behaviour: structural behaviour can be assessed by using simple hand calculations, a time equivalent approach to more extensive computer modelling tools including Abaqus, Ansys and Vulcan. The fire engineer shall be competent in identifying the most appropriate modelling technique for the structural behaviour to be modelled.
- 2.6.2.8 The Designer/practitioner shall need to substantiate that proposed solutions fully meet the intent of the NFPA and the Civil Defence Fire Code and any codes using established fire safety engineering methodology.

Fire and Life Safety Strategy Report

- 2.6.2.9 A Fire and Life Safety Strategy Report shall be prepared and submitted for review to the IRB that covers all of the Works as specified in the Project Brief, the Project Information and this document.

2.6.2.10 The Fire and Life Safety Strategy Report shall identify all required documents to be submitted to demonstrate the manner in which the fire and life safety strategy is implemented.

2.6.2.11 Depending on the scope of the Project, these documents shall include, without limitation:

- a) fire strategy documents for each building, tunnels, viaducts and guideways;
- b) fire engineering report for rolling stock; and
- c) fire engineering report for railway systems.

2.6.3 Fire strategy documents

Purpose of fire strategy documents

2.6.3.1 The fire strategy is a key document or suite of documents, which defines the base fire safety requirements for a building or infrastructure.

2.6.3.2 A line-wide fire strategy shall be developed to outline the design requirements and provisions for the stations and guideway environments.

2.6.3.3 Individual fire strategy documents shall be developed for:

- a) each of the stations;
- b) elevated and at grade guideway sections;
- c) tunnel guideway sections;
- d) portals;
- e) intervention shafts;
- f) escape shafts;
- g) ancillary accommodation such as ventilation buildings, power supply or sub-stations and Depot buildings and facilities; and
- h) control rooms including:
 - i) central control rooms;
 - ii) back up control rooms;
 - iii) depot control rooms; and
 - iv) station control rooms.

2.6.3.4 The purpose of these documents shall be to:

- a) outline the compliance of, and method how the statutory fire and life safety provisions of the premises have been achieved;
- b) outline if additional considerations have been included such as property protection, business continuity, environmental and sustainable concerns;
- c) outline the design assumptions and parameters used in the development of the fire and life safety strategy;

- d) provide a framework for the development of the life safety and evacuation strategy;
- e) provide a framework for the development of the active fire system design requirements;
- f) provide a framework for the development of the passive fire system design requirements;
- g) outline the provisions made for the fire brigade attendance and facilities;
- h) provide a framework for the interface of the premises with any other third party businesses;
- i) outline the management and operational procedures of the fire safety systems and staff duties; and
- j) assist in the future redevelopment or refurbishments of the premises by outlining all the fire and life safety issues in a single document for ease of reference and on-going updating of the document to ensure that it is always 'current'.

Design basis for the fire strategy

2.6.3.5 The fire and life safety strategy shall be developed using the guidance and framework outlined within PAS 911.

2.6.3.6 The fire and life safety strategy shall adopt:

- a) a prescriptive approach – applying existing codes and standards;
- b) a performance-based approach – applying fire safety engineering principles; and
- c) a hybrid of prescriptive and performance based approaches.

2.6.3.7 Typically, and as appropriate to the premises and accommodation types, the fire safety design of a railway system shall consist of all three approaches.

2.6.3.8 The Designers shall be competent in applying and using the three approaches and in identifying the appropriate approach.

Fire strategy inputs

2.6.3.9 In accordance with PAS 911, the development of the fire strategy shall take account of and record the following:

- a) management and system audits – including assessing existing client business, operations and procedures along with codes and standards;
- b) mandatory framework – including taking account of all fire safety legislation as well as insurance requirements;
- c) setting of objectives – including life safety, property protection, business continuity, environmental and extreme events;
- d) risk and hazard assessment – including outline of the risk assessment methodologies, risk profiling, ALARP, and fire modelling techniques such as smoke and evacuation modelling techniques;

- e) building characteristic – including the location of the premises, function and accommodation provided, construction, fire compartmentation, materials and linings as well as plant and services;
- f) occupant characteristic – addressing the type and number of occupants, the evacuation analysis including for people with restricted mobility, and the method for warning; and
- g) practical issues – such as being pragmatic in addressing constraints.

Fire strategy outputs

2.6.3.10 Though a single fire strategy document shall be produced for each premise; in accordance with PAS 911, the report shall outline the following:

- a) fire policy statement;
- b) fire safety (management) strategy;
- c) evacuation strategy;
- d) fire and smoke control strategy;
- e) fire fighting strategy; and
- f) fire protection strategy.

2.6.3.11 All aspects of the proposed fire prevention and control measures shall be coordinated with the Dubai Civil Defence.

2.6.3.12 Final design proposals shall be subject to the approval of the Dubai Civil Defence.

2.6.4 Fire strategy management

2.6.4.1 The design and development of the fire strategy shall include the following for all rail network components, as appropriate:

- a) fire prevention measures;
- b) fire control measures;
- c) fire detection systems;
- d) means of escape;
- e) access for firemen; and
- f) means of fire fighting.

2.6.4.2 Maintenance procedures shall be established to ensure that:

- a) the designed fire and life safety standards are maintained throughout the life of the asset; and
- b) all equipment related to fire and life safety is properly maintained.

2.6.4.3 Management procedures shall ensure that all areas are kept clear of rubbish or any other flammable materials (except where storage of flammable materials is a feature of the building use).

2.6.4.4 In addition to the above, facility-specific fire strategy requirements and considerations are listed below.

Stations

2.6.4.5 The station fire strategy shall seek to reduce the potential sources of fire by addressing the following:

- a) the use of non-combustible or smoke retardant materials wherever possible;
- b) provision of layouts that permit ease of maintenance for equipment and cleaning of the station;
- c) restricting the goods sold within concession units, and providing appropriate fire detection, alarm, fire rated construction, suppressions and smoke ventilation systems;
- d) provision of special storage spaces for combustible materials such as paint, lubricants or oil;
- e) prohibition of smoking and provision of cigarette extinguishing bins at station entrances;
- f) provision of litter bins;
- g) general good housekeeping; and
- h) prohibition of gas based cooking facilities.

2.6.4.6 On detection of a fire, the Dubai Civil Defence shall be informed automatically. Notification of the detector location shall be passed to the Operation Control centre (OCC) and where appropriate to the Station Operation Room (SOR), so relevant fire systems and procedures can be initiated.

2.6.4.7 Evacuation shall be initiated by either the OCC or the SOR (if one exists) of the incident station, appropriate to the railway design and in accordance with the predefined emergency operation procedures.

2.6.4.8 An SOR (if required) shall be designed in accordance with the Civil Defence Fire Code requirements for an emergency command centre.

2.6.4.9 The emergency operation procedure shall avoid unnecessary evacuation in the event of false alarms. Where the operator does not acknowledge the signal within the time delay period, initiation of evacuation shall be automatic by means of announcement over the Public Address (PA) system, activation of emergency exit signs and evacuation messages on the passenger information displays.

2.6.4.10 Management procedures shall ensure that all station staff are trained in the awareness of fire safety at the stations, as well as the specific duties they are expected to perform during a fire incident.

2.6.4.11 Management procedures shall be established to ensure that any new construction, building alterations and changes of room use that may affect the fire safety strategy of the station are in accordance with the applicable standards and guidance documents, approved before they are carried out, and that the relevant fire safety documentation, such as the fire strategy, is revised and updated accordingly.

Ancillary buildings

- 2.6.4.12 Ancillary Buildings include building(s) for intervention points, power supply, ventilation buildings, traction sub-station and storage facilities. Though the functions may differ, there are many common features in these buildings.
- 2.6.4.13 Ancillary buildings shall, where appropriate, be designed in accordance with the requirements of the Civil Defence Fire Code.
- 2.6.4.14 Ancillary buildings are in general unmanned facilities with only the occasional presence of staff for periodic inspection and maintenance purposes. They are not accessible to the public.
- 2.6.4.15 All buildings should be subject to the same high levels of management and maintenance as provided to other railway system buildings under the control of RTA.

Depots

- 2.6.4.16 Depots share many of the fire and life safety features identified for stations. These include:
- a) generally low fire load and low risk use;
 - b) well-defined areas of higher fire load such as storage areas;
 - c) rapid evacuation via normal access routes; and
 - d) high standard of management and maintenance with 24-hour staffing.
- 2.6.4.17 It is appropriate therefore to apply a fire engineering approach, rather than attempting to apply relevant prescribed codes intended to be effective in more conventional type of buildings.

2.6.5 Fire Engineering Reports

Rolling stock

- 2.6.5.1 The Fire Engineering Report shall describe the design approach to systematically identify all fire risks introduced in the design of the rolling stock and the manner in which these risks are managed.
- 2.6.5.2 Fire hazards shall be eliminated where practicable.
- 2.6.5.3 The Fire Engineering Report shall include full justification for the selection of materials (including paints) based on fire characteristics and the results of tests in accordance with recognised international standards.

Railway systems

- 2.6.5.4 The Fire Engineering Report shall describe the design approach to systematically identify all fire risks introduced in the design of the fixed railway systems and the manner in which these risks are managed.
- 2.6.5.5 Fire hazards shall be eliminated where practicable.

- 2.6.5.6 The Fire Engineering Report shall include full justification for the selection of materials (including paints) based on fire characteristics and the results of tests in accordance with recognised international standards.
- 2.6.5.7 The Fire Engineering Report shall include full justification for the selection of cables based on their intended use, fire characteristics and the results of tests in accordance with recognised international standards.

2.7 Security strategy

2.7.1 General

2.7.1.1 The requirements described in this document shall apply except where these are clearly inappropriate to the Project and relaxation has been granted by the relevant Dubai Police departments including Department of Transportation Security and Department of Protective Systems.

2.7.1.2 Where the Project is to be commissioned in phases, the design process shall be implemented in full for the first phase. All design documentation delivered for the first phase shall be updated to include subsequent phases, before each subsequent phase is commissioned.

2.7.2 Overall requirements

Security planning and design

2.7.2.1 The security planning and design shall encompass the latest industry standards, innovations, emerging design trends, and technology developments impacting security in transportation systems and the building industry.

2.7.2.2 The security planning and design shall follow the directives of Dubai Police.

2.7.2.3 The security planning and design shall follow a comprehensive approach, integrating the Project system design, technology, and operations.

- a) design includes architecture, engineering, site planning, landscape design, and interior design;
- b) technology refers to the electronic devices that are installed in and around buildings and sites; and
- c) operations are the Operator's policies and procedures for running the system.

2.7.2.4 The security planning and design shall consider transparent security strategies for the Project including but not limited to:

- a) design of stations shall incorporate architectural planning for:
 - i) clear circulation and visibility;
 - ii) crime prevention through environmental design (CPTED) principles, and
 - iii) accommodate the needs of first responders inside and outside stations.
- b) utilising blast resistant design and materials where possible, to minimise flying glass shards and building debris during and after a blast;
- c) site planning which shall maximise building setbacks from the street, to mitigate the impact of vehicle bombs. Distance equals safety;
- d) developing a layered defence for site planning and architectural building design, with attention to the site perimeter, the first line of defence;

- e) using street furniture engineered to stop speeding vehicles, plantings, level changes, and public art at public spaces facing roadways, to prevent vehicles from ramming a facility. Where space allows, these elements may be installed instead of rows of bollards and concrete barriers;
- f) designing structural engineering systems to avoid progressive collapse in the event of a blast;
- g) designing mechanical and electrical systems to mitigate airborne threats, and minimise air distribution of hazardous materials in ventilation systems;
- h) providing redundancy for all major building systems and utilities in the event one power or water source is unavailable or taken out;
- i) locating redundant water and power sources remotely from each other;
- j) incorporating access control systems including master key and key watch systems;
- k) incorporating biological and chemical sensor technology, explosive detection devices, video, wireless communications, and computer software to simulate the spread of potential contaminants; and
- l) planning for an all-hazards emergency response approach to disasters and worst-case scenarios, such as simulated explosions on vehicles, or simultaneous explosions at several stations.

2.7.2.5 The security planning and design shall provide for a comprehensive transfer of security strategy and technology knowledge to the Project Operator including a security hazard log and inputs into procedural documentation and training.

2.7.3 Security risk analysis

2.7.3.1 A threat, vulnerability and risk analysis (TVRA) shall be incorporated throughout the design process to provide the data to be used in developing security design countermeasures to mitigate damage and loss. The analysis shall cover areas including, but not limited to:

- a) blast from Improvised Explosive Devices (IEDs);
- b) blast from Vehicle-Borne IEDs (VBIEDs);
- c) blast from suicide bomber IEDs, including backpacks;
- d) chemical, biological, radiological and nuclear (CBRN) materials;
- e) crime;
- f) power loss;
- g) cyber-terrorism; and
- h) data loss.

2.7.3.2 The TVRA shall identify the cause and effect of security risks and categorise and track mitigations through design or procedure.

2.7.3.3 A multi-disciplinary team shall be appointed to address the various planning criteria that apply to each site in the Project system. The fields of architecture, construction, systems

engineering, security, law enforcement and rail operations management shall be represented on the team.

Risk estimation

- 2.7.3.4 Security hazards shall be assessed using the principles of the CENELEC standard EN 50126 by the severity of the respective hazardous event.
- 2.7.3.5 The assessment of hazards shall take into account the national threat levels issued by Dubai Police.
- 2.7.3.6 The severity of hazard consequences to persons or environment and frequency of occurrence of a hazardous event shall be categorised into different hazard severity levels as per EN 50126.

Risk evaluation

- 2.7.3.7 A risk shall be considered as the combination of the severity and the probability of occurrence of a hazardous event. Risk evaluation shall be carried out in accordance with requirements of EN 50126.

Risk control

- 2.7.3.8 The strategy for risk reduction shall follow the principle that all identified risks shall be reduced to a level "as low as reasonably practicable" (ALARP) by implementing risk control measures.
- 2.7.3.9 In principle, these measures shall take the following precedence:
 - a) eliminate identified hazards or reduce associated risk through design;
 - b) isolate hazardous materials, components and operations from other activities, areas, personnel and incompatible material;
 - c) minimise the risk from hazards that cannot be eliminated by technical measures including interlocks, redundancy, system protection equipment and devices;
 - d) when alternative design approaches cannot eliminate or mitigate the hazards, physical control methods shall be provided; and
 - e) as a last resort to eliminate or mitigate risk, security rules and procedures shall be developed and adequate training of Operator's staff provided.

Security hazard log

- 2.7.3.10 The Security Hazard Log shall be the principle means for recording information on identified hazards and any measures applied, following analyses, to remove them or control associated risks to as low as reasonably practicable.
- 2.7.3.11 The Security Hazard Log shall enable the actual status and progress of the risk management to be monitored throughout all stages of the Project.

2.7.3.12 The details of each hazard and the associated risk control measures shall be recorded and stored in the Hazard Log in the form of a database for tracking the status of hazard resolution with documented evidence.

2.7.3.13 Ownership of the Security Hazard Log shall be transferred to the Project Operator upon proof of safety certification.

2.7.4 Security strategy

2.7.4.1 Based on the TVRA, the Project design shall provide an overall security strategy that covers all of the Works within the scope of the Project.

2.7.4.2 The security strategy shall adopt one of the following:

- a) a prescriptive approach: applying applicable codes and standards;
- b) a performance-based approach: applying recognised security engineering and management principles; and
- c) a hybrid of prescriptive and performance based approaches.

Security strategy reports

2.7.4.3 The security strategy will be captured in a Security Strategy Report which shall identify all required documents to be submitted to demonstrate the manner in which the security strategy is implemented.

2.7.4.4 Depending on the scope of the Works, the Security Strategy Report shall include, without limitation:

- a) security strategy for stations;
 - b) security strategy for rolling stock;
 - c) security strategy for the Project system alignment including tunnels and viaducts and ancillary accommodation such as ventilation buildings, power supply or sub-stations buildings;
 - d) security strategy for depots including depot building accommodation such as workshops, administration buildings, operations control centres; and
 - e) security strategy for computer based and IT systems;
- together with the manner in which these risks are managed.

2.7.4.5 The reports shall include full justification for the design characteristics referencing international standards or recognised examples of best practice.

2.7.4.6 The security strategy report shall be a key document or suite of documents, which defines the base security requirements for a building or infrastructure. A Project system-wide strategy shall be developed to document the design requirements and provisions for the Project components as described in clause 2.7.4.4 above.

2.7.4.7 The purpose of these documents shall be to:

- a) demonstrate how the statutory security provisions of the premises have been achieved;
- b) outline if additional considerations have been included such as property protection, business continuity, environmental and sustainability concerns;
- c) outline the design assumptions and parameters used in the development of the security strategy;
- d) provide a framework for the development of the Operator's security management strategy;
- e) provide a framework for the development of the active and passive security system design requirements;
- f) outline the provisions made for Dubai Police interfaces and facilities;
- g) provide a framework for the interface of the premises with any other third party businesses;
- h) outline the management and operational procedures of the security systems and staff duties; and
- i) assist in the future redevelopment or refurbishments of the Project system by outlining all the security issues in a single document for ease of reference and on-going updating of the document to ensure that it is always 'current'.

2.8 Ergonomics and accessibility

2.8.1 General

2.8.1.1 Ergonomics is a means to ensure safety, occupational health and accessibility. The requirements described in this section shall apply except where these are clearly inappropriate to the Works and relaxation has been granted by the IRB.

2.8.2 Key principles in design

2.8.2.1 Ergonomics shall be recognised as a key element to design safety at every level and function of the Project system lifecycle and the demonstrated application of ergonomics and human factors in design shall be a requirement of the Systems Assurance process.

2.8.2.2 End users shall be involved in the design process. This shall include members of the public, and operations and maintenance staff.

2.8.2.3 Ergonomics and human factors shall consider anthropometrics including body strength and mental capability.

2.8.2.4 Ergonomics and human factors considerations shall be given to all foreseeable operating conditions including normal, degraded and emergency operating conditions.

2.8.2.5 Ergonomics and human factors considerations shall be given to the management of human error to ensure that people cannot make certain predictable sorts of error or to help users to review their decisions before enacting them.

2.8.2.6 Through ergonomics, environments shall be created in which people can make errors without dire consequences.

2.8.3 Ergonomic studies

2.8.3.1 Ergonomic design studies covering the ergonomics and human factors for the design of the Project system shall be carried out in accordance with the Developer Guidelines and submitted to the IRB for review and approval.

2.8.3.2 As a minimum, the ergonomic study shall consider the following areas that will have a direct impact on human performance:

- a) Design:
 - i) user centred designs;
 - ii) equipment design;
 - iii) function allocation;
 - iv) workplace design;
 - v) task analysis; and
 - vi) job design.
- b) Conditions:
 - i) environment;

- ii) shift work;
 - iii) workload and fatigue management;
 - iv) stress; and
 - v) morale and motivation.
- c) Staffing:
- i) selection including anthropometrics;
 - ii) recruitment; and
 - iii) retention.
- d) Culture:
- i) communication;
 - ii) team working;
 - iii) management;
 - iv) leadership; and
 - v) change.
- e) Training:
- i) training needs analysis;
 - ii) cost effective training; and
 - iii) supervision and appraisal.

2.8.3.3 The ergonomic studies shall ensure design submissions are able to demonstrate that appropriate ergonomic and human factors considerations have been given to the design, commissioning, and operation of Project system equipment under normal, degraded and emergency operating conditions.

2.8.3.4 The use of three dimensional modelling, mock ups and design “fly throughs” shall be emphasised to present the different solutions studied in function of the existing ergonomic and functional constraints. Each solution shall be analysed with the following criteria:

- a) appropriateness to the requirements;
- b) conformity to ergonomic standards;
- c) future development capability; and
- d) cost.

2.8.4 Standards

2.8.4.1 Equipment shall be designed in accordance with key ergonomics standards, including EN614 Parts 1 and 2.

2.8.4.2 Control rooms shall be designed in accordance with key ergonomics standards, including EN11064, EEMUA 191 and EEMUA 201.

2.8.4.3 BS 5940 Part 1 (1980) shall be referred to for design and dimensions of office workstations, desks, tables and chairs.

2.8.5 Minimum facilities to be covered by ergonomic studies

2.8.5.1 Ergonomics and Human Factors considerations shall be given to all foreseeable operating environments, including, but not limited to, the following:

- a) operations control centres;
- b) incident control centres;
- c) back up control centres;
- d) depot control rooms;
- e) station control rooms;
- f) train cabs and driving consoles;
- g) ticketing offices;
- h) public information booths;
- i) AFC vending machines;
- j) AFC gates;
- k) seating, handrails and hand held provisions in vehicles;
- l) passive and active signage;
- m) passenger information display systems;
- n) alarm and communication devices to be used by the public;
- o) emergency devices (e.g. vehicle door release, fire alarm call point, fire hose reels etc) be used by operations staff and the public;
- p) workshops and maintenance facilities; and
- q) others as appropriate to the nature of the Project.

2.8.6 Accessibility

2.8.6.1 The Project shall facilitate access and use by persons with special needs in accordance with the RTA's Guidelines for Accessible Transport in the Emirate of Dubai.

2.8.6.2 International standards may also be used to supplement the above referenced document where appropriate and subject to the approval of the IRB.

2.9 Compliance with standards and legislations

2.9.1 Introduction

2.9.1.1 The Developer Guidelines defines the relationship between it and other standards, codes of practice and the statutory requirements of Dubai.

2.9.2 Legislation

2.9.2.1 All designs shall comply with the relevant laws of the UAE and Dubai.

2.9.2.2 Relevant legislation will be identified in the Developer's Project Brief but the responsibility to ensure that all applicable legislation has been identified remains with the Developer's appointed Designer / Contractor.

2.9.3 Regulations

2.9.3.1 All designs shall comply with the relevant regulations issued by statutory agencies with jurisdiction in Dubai.

2.9.3.2 All designs shall comply with applicable regulations issued by the RTA.

2.9.3.3 The responsibility to ensure that all applicable regulations have been identified remains with the Developer's appointed Designer / Contractor.

2.9.4 General approach to standards

2.9.4.1 The hierarchy of standards shall be as follows:

- a) UAE Federal Codes and Standards; and
- b) Dubai standards (in no particular order):
 - i) Dubai Civil Defence;
 - ii) Dubai Electricity & Water Authority;
 - iii) Roads & Transport Authority; and
 - iv) Dubai Municipality.

2.9.4.2 The design management procedure shall require each design submission to be supported as appropriate by a reference to the standards on which the design is based.

2.9.4.3 Designs shall be based on the preferred reference standards (see below) in the Developer Guidelines unless otherwise accepted by the IRB.

2.9.4.4 Related design elements shall be based on reference standards from the same source.

2.9.4.5 For each standard quoted as the basis for a design submission, the most recently published version at the time of the Project's invitation to tender shall apply, unless otherwise agreed with the IRB.

2.9.4.6 The consistent application of standards is required.

2.9.4.7 Mixing and matching of standards from different sources for related design criteria is not permitted.

2.9.4.8 Where standards referred to are not already recognised by the RTA as being acceptable to transport systems in Dubai (i.e. standards that are different to those cited in the RPDG), evidence shall be provided to the IRB for verification demonstrating that the quality of the design to the reference standard is equivalent to a design based on the corresponding recognised standard.

2.9.5 Preferred reference standards

2.9.5.1 The preferred reference standards to be adopted for Projects where practicable are:

- a) European Norms (Eurocodes) published in the English language under BS EN references. These may be regarded as the Primary reference standards;
- b) International standards published and supported by:
 - i) UIC;
 - ii) IEC;
 - iii) ITU;
 - iv) ETSI;
 - v) NFPA;
 - vi) ASTM; and
 - vii) ISO;
- c) Professional bodies such as:
 - i) IET (Institute of Engineering and Technology – formerly the Institute of Electrical Engineers)
- d) British Standards (only where not superseded by an equivalent European Norm)

2.9.5.2 Projects may adopt other reference standards but the Developer needs to:

- a) demonstrate that these are relevant, well established and will ensure similarly high levels of safety and performance; and
- b) show that it will not mix standards from different regions, or based on different principles, or that (if this is necessary at some interfaces) the risks have been carefully analysed and mitigated.

2.9.6 Reference standards in the Developer Guidelines

2.9.6.1 Standards quoted, in whole or in part, within this document shall be treated as requisite for the application of the Developer Guidelines.

2.9.6.2 Where a reference is part of a complete standard which contains alternative requirements, then depending on the particular application, only the relevant parts of this standard shall be considered.

2.9.6.3 Where inappropriate to work in Dubai, specific elements of a reference standard may be disregarded or qualified, subject to the approval of the IRB.

2.9.7 Codes of practice

- 2.9.7.1 Where there are no appropriate reference standards that can be applied to the design or design implementation process, relevant codes of practice published by professional institutions (or similar organisations) shall be applied.
- 2.9.7.2 UAE and Dubai codes of practice shall take precedence over codes published in other countries.

2.9.8 Version Control

- 2.9.8.1 For all legislation, regulations, standards and codes of practice, the most recently published version when the Project Brief was issued to the RTA shall apply.

2.9.9 Local design criteria

- 2.9.9.1 For Dubai climatic design criteria refer to section 3.2 of this document.

3 Design principles

3.1 Introduction

3.1.1.1 This chapter presents design guidelines and principles whose adoption, though optional to a Developer, would help demonstrate compliance with the primary objectives for railway projects in Dubai (covered in section 1.3 above) and would facilitate RTA's issuing of Permits and Safety Certificates.

3.2 Dubai climate and environment

3.2.1 General

3.2.1.1 This section presents the Dubai-specific climatic and environmental design criteria that need to be addressed in the design of railway projects in Dubai.

3.2.1.2 It is imperative that the Developer, and its appointed Designer/Contractor, confirm with the IRB that standards proposed for the design of the Project (particularly when different to those cited in RPDG) are indeed suitable for implementation in the Dubai environment. For guidance, one may refer to RPDG's Volume 3 (Civil Engineering), Part 1, Appendix 5 (Modifications to UK National Annex Clauses for Use of Eurocodes) which provides a list of Eurocode clauses that have been amended to suit the structural design of all railway structures and buildings within the emirate of Dubai.

3.2.2 Climatic design criteria and environmental considerations

3.2.2.1 The climatic design criteria described herein are minimum requirements that should be taken into account in the design of the Project. The Designer should determine the worst case conditions for any specific Project in order to ensure a solution that is fit for purpose.

3.2.2.2 All climatic conditions arising from any cause whatsoever should be taken into account, including:

- a) river flooding;
- b) excessive precipitation;
- c) extremely high temperature,
- d) high solar intensity;
- e) high humidity;
- f) high winds;
- g) dust-storms;
- h) sand storms and drifting sand;
- i) lightning;

- j) high ozone levels;
- k) high concentrations of salinity, chlorides and sulphates in soil, ground water and air;
- l) water table height;
- m) marine environment restrictions; and
- n) any other inclement weather conditions.

3.2.2.3 The following climatic conditions may be taken into account in the design of the Project:

- a) Height above sea level: < 100m;
- b) Maximum ambient temperature: +52°C;
- c) Minimum ambient temperature: +1°C;
- d) Maximum ambient humidity: 100%;
- e) Minimum ambient humidity: 20%;
- f) Maximum wind velocity: 160km/h;
- g) Rainfall rate in 24 hours for a return period of 50 years: 116mm;
- h) Average yearly precipitation: 80mm;
- i) Earthquake Loading: 0.07g; and
- j) Soil thermal resistivity: 2°C/m/w
- k) The climate in the location of the Project is relatively mild from November to April and hot from May to October with high relative humidity;
- l) Under certain combinations of the above climatic conditions considerable condensation may take place. Particular attention should be paid to the prevailing corrosion conditions. A considerable amount of salt is contained in the atmosphere which together with the extremely high ambient humidity, can produce severe corrosion problems;
- m) Distribution of precipitation is irregular and the precipitation amounts are normally of no significance, but attention should be paid to the fact that sudden heavy precipitation in a very short period of time can occur which can cause flooding;
- n) The prevailing wind directions are from North and West. Strong winds are common and sand-storms and/or dust-storms occur in the summer months; and
- o) Direct exposure to the sun may result in temperatures considerably higher than the ambient temperature.

3.2.2.4 All elements of the Project should be adequately designed and specified for reliable and correct operation under worst case climatic conditions.

3.2.3 Sandstorms

3.2.3.1 The design of the Project should accommodate the possible impact of sandstorms, including consideration of the following adverse effects:

- a) accumulation of sand on the railway track;
- b) accumulation of sand and dust on external parts of the Works;
- c) accumulation of sand at the open at-grade areas around the facilities;
- d) ingress of sand and dust through station and tunnel openings;
- e) ingress of sand through ventilation system louvres;
- f) ingress of sand and dust through station doors;
- g) ingress and mixing of sand and dust at cooling towers and other outdoor facilities;
- h) ingress of sand into the road side drains;
- i) abrasion of coatings due to flying sand;
- j) ingress of sand and dust into equipment; and
- k) clogging of equipment dust filters by sand and dust.

3.2.4 Rainstorms

3.2.4.1 The design of the Project should accommodate the impact of rainstorms, including consideration of the following adverse effects:

- a) surface storm water drainage around the station areas;
- b) drainage of large areas of roofs;
- c) ingress of water into underground stations through entrance and vent shaft openings;
- d) ingress of water into tunnels through portals and other openings;
- e) leakage through roof and façade; and
- f) threshold level of at-grade areas with openings to underground stations.

3.2.4.2 Hydraulic design of stormwater drainage systems and clear time for all rail facility areas should be in accordance with Dubai Municipality Drainage and Irrigation Department's Sewerage and Drainage Design Criteria.

3.2.4.3 Designs should be checked to ensure the drainage system and other infrastructure is capable of withstanding a 1 in 100 year event such that:

- a) the duration of any restriction is minimal, and
- b) water is able to drain away sufficiently quickly following such an event.

3.2.5 Seismic conditions

3.2.5.1 The Project should be designed to withstand the Seismic conditions in Dubai and should be in accordance with Dubai Municipality's earthquake load requirements as stipulated in their Building Code Regulations and Construction Specifications.

3.2.5.2 The seismic actions should be based on the geological profile of the site area.

3.2.5.3 The design should use a compatible set of seismic actions, partial factors and combinations with other actions.

3.2.5.4 Analytical data should be provided to confirm that the Works conform to applicable earthquake resistance standards.

3.2.6 Flood protection

3.2.6.1 All necessary protective measures should be made to ensure that the Works areas do not become flooded at any time.

3.2.6.2 All arrangements for flood protection should, as a minimum, meet the requirements of Dubai Municipality Drainage and Irrigation Department as stipulated in their Sewerage and Drainage Design Criteria.

Flood protection plan

3.2.6.3 A Flood Protection Plan should be prepared and shall:

- a) review the topography, the local and global drainage network, any tidal effect, sequencing of construction activities and the risk of flooding on adjacent properties, tunnels and facilities;
- b) be submitted to the IRB prior to the commencement of excavation or drainage works on site;
- c) identify the areas that are at risk from flooding; and
- d) examine the potential consequences of any flooding and shall make proposals to prevent flooding.

Design flood level

3.2.6.4 The Design Flood Level should be derived from the highest flood levels;

3.2.6.5 The Design Flood Level should be taken as 1m above the highest recorded flood level at each location; and

3.2.6.6 For areas with no flood record, Design Flood Level should generally be 1m above the existing ground or road level.

3.3 Environmental sustainability

3.3.1 General

- 3.3.1.1 The Developer and its appointed Designer should ensure that sustainability features are incorporated into the design of Projects where feasible to minimise water and energy consumption and maximise usage of natural and renewable sources of energy.
- 3.3.1.2 The Developer and its appointed Operator / Maintainer should ensure that sustainable practices are employed to optimise water and energy consumption and minimise waste production during facility operation and maintenance.
- 3.3.1.3 The following particular requirements are provided as guidance to help Developers, and their appointed Designers and Operators, achieve the above objectives.

3.3.2 Water Resources - Stations

- 3.3.2.1 Water efficiency measures such as water metering and leak detection devices should be incorporated in the design of buildings to reduce water consumption during operation.
- 3.3.2.2 Grey water should be recycled in accordance with the DEWA Standards where practical.
- 3.3.2.3 Landscaped areas shall be irrigated using Treated Sewage Effluent (TSE) to reduce potable water consumption requirements of the stations. The TSE will be in accordance with the DEWA Standards and irrigation design shall meet the requirements of Dubai Municipality Drainage and Irrigation Department.

3.3.3 Water Resources - Depots

- 3.3.3.1 Water efficiency measures such as water metering and leak detection devices may be incorporated in the design of buildings to reduce water consumption during operation.
- 3.3.3.2 The use of solar hot water heating (solar thermal) in high demand areas may be considered.
- 3.3.3.3 Wastewater from rain washes, bogie washes, blow down and other such systems may be treated and re-cycled.
- 3.3.3.4 A system should be provided to capture waste oil and grease for appropriate disposal.
- 3.3.3.5 Grey water should be recycled in accordance with the DEWA Standards where practical.

3.3.4 Energy Consumption - Mechanical Systems

- 3.3.4.1 Intelligent and efficient lighting systems should be considered to minimise lighting requirements.
- 3.3.4.2 Efficient and well-maintained vehicles should be used.
- 3.3.4.3 Effective planning should be carried out to minimise the concurrent use of plant and equipment in various areas of the site thus reducing fuel consumption.
- 3.3.4.4 Low ultra sulphur fuel may be considered for construction vehicles and equipment and specify electrical vehicles onsite.

3.3.4.5 The incorporation of photovoltaic (PV) elements, including solar panels, may be considered at stations, ancillary buildings and depot roof areas and maintenance sheds. Siting and maintenance of PV panels shall be required to ensure efficient operation.

3.3.4.6 Solar thermal heating may be considered for water heating, or alternatively producing hot water only when required thus minimising the need for storing heated water.

3.3.5 Energy Consumption - Rolling Stock

3.3.5.1 Regenerative braking should be used to export energy back into system.

3.3.5.2 The use of on-board energy storage devices may be considered in addition to regenerative braking.

3.3.5.3 Intelligent and efficient lighting systems should be considered to minimise lighting requirements. Energy efficient lighting should be specified for the rolling stock.

3.3.5.4 Door types and their modes of operation should be selected to minimise loss of conditioned air.

3.3.5.5 Low ultra sulphur fuel may be considered for maintenance vehicles and equipment.

3.3.6 Energy Consumption - Guideway

3.3.6.1 Energy humps should be integrated into the vertical alignment between stations to reduce energy consumption where practicable to do so.

3.3.6.2 The use of trackside energy storage devices or inverter substations should be considered.

3.3.7 Energy Consumption - Stations

3.3.7.1 All potential sources of energy should be reviewed and a sustainable energy strategy should be developed for the stations.

3.3.7.2 Building envelopes should incorporate adequate thermal insulation to reduce interior cooling demands.

3.3.7.3 The incorporation of PV elements, including solar panels, may be considered and evaluated for cooling power on building roofs. Siting and maintenance of PV panels shall be required for their efficient operation.

3.3.8 Energy Consumption - Depots

3.3.8.1 All potential sources of energy should be reviewed and a sustainable energy strategy should be developed for the building.

3.3.8.2 Building envelopes should incorporate adequate thermal insulation to reduce interior cooling demands.

3.3.8.3 The incorporation of PV elements, including solar panels, may be considered and evaluated for cooling power on building roofs. Siting and maintenance of PV panels shall be required for their efficient operation.

3.3.8.4 Effective planning should be undertaken to minimise the concurrent use of plant and equipment in various areas of the site thus reducing energy consumption.

- 3.3.8.5 Efficient and well-maintained maintenance vehicles should be specified.
- 3.3.8.6 Low ultra sulphur fuel may be considered for maintenance vehicles and equipment.
- 3.3.8.7 The use of electric maintenance vehicles in depots should be considered.

3.3.9 Building Environment - Guideway

- 3.3.9.1 Subject to the approval of the relevant authorities, existing linear structures (highways) may be used where possible to reduce the visual intrusion on the urban landscape.
- 3.3.9.2 The elevated alignments should also be designed to provide shading for the immediate surrounding environs.

3.3.10 Building Environment - Stations

- 3.3.10.1 Multimodal access should be provided to the stations and space for bicycle racks and parking spaces for low-emissions vehicles as per Dubai Municipality requirements should also be allocated. Connections should be made to the existing or planned surrounding footpath/ cycle path network.
- 3.3.10.2 The orientation and siting of the station should be investigated to ensure the building can provide outdoor shading.
- 3.3.10.3 A shading strategy which includes heat purge measures should be produced. Shading devices such as trees and / or canopies should be located at key areas along walkways and at station entrances for shading purposes.
- 3.3.10.4 The building should be designed to reduce the need for glazing and should specify glass that reduces heat gains.
- 3.3.10.5 The design of building envelopes should be suited for the local environment and materials which require minimal cleaning should be specified and used.
- 3.3.10.6 The use of daylight should be maximised to minimize the energy load of artificial lighting and provide a superior indoor environmental quality.
- 3.3.10.7 Stations should also be designed to maximize natural ventilation to reduce reliance on mechanical ventilation.

3.3.11 Building Environment - Depots

- 3.3.11.1 Multimodal access should be provided to the depots and space for bicycle racks/storage and parking spaces for low-emissions vehicles should also be allocated. Connections should be made to the existing or planned surrounding footpath / cycle path network.
- 3.3.11.2 The building should be designed to reduce the need for glazing and should specify glass that reduces heat gains.
- 3.3.11.3 The design of building envelopes should be suited for the local environment and materials which require minimal cleaning should be specified and used.
- 3.3.11.4 The use of daylight should be maximised to minimize the energy load of artificial lighting and provide a superior indoor environmental quality.

- 3.3.11.5 Passive ventilation should be considered in particular for smoke extraction where practical.
- 3.3.11.6 Consideration should be given to minimising internal barriers for light penetration such as high-level access platforms.
- 3.3.11.7 High bay lighting may be considered as a more efficient lighting system. Furthermore, the design should also consider an appropriate ceiling height to allow for natural daylight penetration into the depot.
- 3.3.11.8 Alternative forms of cleaning may be considered such as underframe cleaning which uses recycled water rather than compressed air cleaning which generates air particulates.

3.3.12 Materials - General

- 3.3.12.1 Construction materials should be specified from the DM Approved Materials List where appropriate.
- 3.3.12.2 All proposed green building materials shall be tested at Dubai Central Laboratory (DCL) accredited testing facilities. The testing report should include the physical, mechanical, chemical, thermal and fire resistance of green building materials.

3.3.13 Materials - Rolling Stock

- 3.3.13.1 Body types and materials should be specified that are durable for the operational life of the rolling stock and minimise weight to save energy consumption.
- 3.3.13.2 The thermal coating for the inside of the rolling stock may be specified to minimise cooling needs and provide good thermal performance.
- 3.3.13.3 The types of braking pads should be resilient to minimise waste disposal and the need for friction braking shall be minimised.

3.3.14 Materials - Guideway

- 3.3.14.1 A study of materials available within the UAE and the region should be undertaken, in particular for steel and concrete. The design specifications for concrete may investigate options for reducing the amount of Portland cement by incorporating waste products such as fly ash and blast furnace slag.
- 3.3.14.2 Materials and techniques which minimise noise and vibration during operation of the rolling stock such as floating track slabs and resilient rail fastening and baseplates should be specified as appropriate.
- 3.3.14.3 Construction waste should be reused onsite where practical. For example, concrete waste may be reused as a sub-base material for non-structural components.
- 3.3.14.4 Spoil generated during construction may be reused onsite to minimise waste disposal to landfill.

3.3.15 Materials - Stations

- 3.3.15.1 A study of materials available within the UAE and Region should be undertaken. Based on the results, local materials which are sympathetic to the local environment should be specified in the design.
- 3.3.15.2 Components which can be prefabricated offsite may be specified to reduce waste onsite.
- 3.3.15.3 Appropriate recycling facilities may be provided within the station environs which should include as a minimum paper, aluminium, glass and plastics.

3.3.16 Materials - Depots

- 3.3.16.1 A study of materials available within the UAE and Region should be undertaken. Based on the results, local materials should be specified in the design which is sympathetic to the local environment.
- 3.3.16.2 Components which can be prefabricated offsite should be specified to reduce waste onsite.
- 3.3.16.3 Appropriate recycling facilities may be provided within the depot environs which should include as a minimum paper, aluminium, glass, plastics and steel.
- 3.3.16.4 Appropriate containment areas should be allocated for hazardous materials and waste onsite to facilitate collection and appropriate disposal.

3.4 Electromagnetic compatibility

3.4.1 General

3.4.1.1 In addition to the overall EMC requirements and processes covered in section 2.5, the following particular requirements are provided as guidance to help Developers ensure that their Projects do not create, or are susceptible to, electromagnetic disturbance and are safe to the general public, passengers and railway staff.

3.4.2 EMC requirements for rolling stock

3.4.2.1 All equipment and systems supplied should be able to withstand without fault, power supply surges, interference and transients as may be caused by power and traction supplies, switching effects and lightning impact.

3.4.2.2 Rolling stock should have full electromagnetic compatibility with other equipment to be installed along the line, in the stations and in the depot area.

3.4.2.3 Where appropriate, anti-surge or other protective devices should be provided to fully protect the rolling stock against electromagnetic interference.

3.4.2.4 Shielding and filtering should be provided where required to ensure that any conducted or radiated interference is eliminated or reduced below the level of susceptibility of equipment or domestic or industrial appliances installed in the vicinity of the Project prior to commencement of commercial operation.

3.4.2.5 All design documentation, test specifications and test reports should be submitted for review and all tests, with the exception of commissioning tests, should be completed prior to the delivery of the first rolling stock vehicle.

3.4.2.6 The rolling stock radiated emissions should not affect any equipment operating in the vicinity, which are susceptible to the radiated electromagnetic waves from the rolling stock. These equipment may include but are not limited to:

- a) heart pacemakers;
- b) public broadcast services and communication service;
- c) radio systems;
- d) fixed line communication systems;
- e) trackside signalling and train control equipment;
- f) equipment used by track based personnel;
- g) police and fire department equipment particularly if in close proximity;
- h) mobile radios;
- i) hospital equipment particularly if in close proximity;
- j) highway traffic control systems;
- k) mobile phones;

- l) public information display systems (PIDS);
 - m) CCTV systems;
 - n) station public address systems; and
 - o) station fire detection, alarm and suppression equipment.
- 3.4.2.7 The maximum levels of radiated EMI of any individual item of vehicle mounted equipment should not exceed the levels specified in EN 50121-3-2. The emissions of the vehicle should not exceed the levels specified in EN 50121-3-1. These limits apply under all normal conditions.
- 3.4.2.8 All electrical and electronic equipment on board the vehicle should not exceed the conducted interference levels as defined in EN 50121-3. These limits apply under all normal conditions.
- 3.4.2.9 The possible external and internal sources of emission include:
- a) radio systems in the vicinity of the Project;
 - b) traction and auxiliary equipment including the auxiliary converters and lighting inverters;
 - c) mobile phones/portable radios; and
 - d) magnetic fields from motors and traction power supply conductors.
- 3.4.2.10 On board equipment sensitive to the sources as referred to above may include, but not be limited to:
- a) train public address;
 - b) traction/braking control systems;
 - c) auxiliary inverter;
 - d) train radio;
 - e) DFIS screen;
 - f) CMS;
 - g) Video broadcasting system;
 - h) PIDS; and
 - i) CCTV.
- 3.4.2.11 All electrical and electronic equipment on board the vehicle should be immune to any radiated electromagnetic energy produced by other pieces of rolling stock equipment and external sources as required by EN 50121-3.
- 3.4.2.12 The mounting of sensitive equipment in the vicinity of the on board radio antennas should be avoided.
- 3.4.2.13 Any equipment sensitive to electrostatic discharge likely to be touched by personnel should be protected against electrostatic discharge. Equipment should be tested to 3 kV with contact discharge, as defined in EN 50121-3.

3.4.2.14 Protection should also be provided where required for on board signalling and communications equipment not covered by EN 50121-3 or EN 50238.

3.4.3 Particular requirements for signalling and communications

3.4.3.1 Signalling and communications equipment and systems should comply with the specific requirements of EN 50121-4.

3.4.4 Particular requirements for power supply and other electrical systems

3.4.4.1 Power supply and related electrical systems should comply with the specific requirements of EN 50121-5.

3.4.5 Particular requirements for other electrical systems

3.4.5.1 Other electrical systems should comply with the general performance requirements EN 50121-1.

3.4.5.2 Lifts, escalators and moving walkways should comply with the specific requirements for emission and immunity in EN 12015 and EN 12016 respectively.

3.4.6 List of applicable EMC standards

3.4.6.1 Applicable EMC standards that should be considered are as follows:

- a) International/European Standards
 - i) EN 55022 Limits and Methods of Measurement of Radio Interference Characteristics of Information;
 - ii) EN 55024 Information technology equipment – Immunity characteristics – Limits and methods of measurement;
 - iii) EN 50061 EMC Standard for Cardiac Pacemaker;
 - iv) EN 50121 series Railway Applications – EMC Part 1 to 5;
 - v) EN 61000-6-1 EMC Generic Immunity Standard Part 6-1 - Domestic and Light Industries;
 - vi) EN 61000-6-2 EMC Generic Immunity Standard Part 6-2 - Industrial environment;
 - vii) EN 61000-6-3 EMC Generic Emission Standard Part 6-3 - Domestic and Light Industries;
 - viii) EN 61000-6-4 EMC Generic Emission Standard Part 6-4 - Industrial environment;
 - ix) EN 50122-1 Rail Applications – Fixed installations Part 1 Protective provisions relating to electrical safety and earthing;
 - x) EN 61000-4-1 Electromagnetic compatibility EMC Part 4-1: Testing and measuring techniques – Overview of EN 61000-4;
 - xi) EN 61000-4-2 Electromagnetic compatibility EMC Part 4-2: Testing and measuring techniques – Electrostatic discharge requirements;

- xii) EN 61000-4-3 Electromagnetic compatibility EMC Part 4-3: Testing and measuring techniques – Radio frequency electromagnetic field–immunity tests;
 - xiii) EN 61000-4-4 Electromagnetic compatibility EMC Part 4-4: Testing and measuring techniques – Electrical fast transient/burst requirements;
 - xiv) EN 61000-4-5 Electromagnetic compatibility EMC Part 4-5: Testing and measuring techniques – Surges immunity tests;
 - xv) EN 61000-4-6 Electromagnetic compatibility EMC Part 4-6: Testing and measuring techniques – Conducted radio-frequency disturbances above 9 kHz immunity tests;
 - xvi) EN 61000-4-8 Electromagnetic compatibility EMC Part 4-8: Testing and measuring techniques – Power frequency magnetic field immunity tests;
 - xvii) EN 61000-4-11 Electromagnetic compatibility EMC Part 4:11: Testing and measuring techniques – Voltage dips, short interruptions and voltage variations immunity tests;
 - xviii) EN 50081-1 EMC Generic Emission Standard;
 - xix) EN 50082-2 EMC Generic Immunity Standard;
 - xx) EN 12015 Electromagnetic compatibility- Product family standard for lifts escalators and passengers conveyors – Emission;
 - xxi) EN 12016 Electromagnetic compatibility- Product family standard for lifts, escalators and passenger conveyors – Immunity;
 - xxii) EN 50238 Railway applications — Compatibility between rolling stock and train detection systems;
 - xxiii) EN 50130-4 Alarm systems - Part 4: Electromagnetic compatibility — Product family standard: Immunity requirements for components of fire, intruder and social alarm systems.
- b) Other standards
- i) ITU Recommendation K-series - Protection against interference
 - ii) ITU Directives Concerning the protection of telecommunication lines against harmful effects from electric power and electrified railway lines, Vol. VI Danger and disturbance.
 - iii) ITU Directives Concerning the protection of tele-communication lines against harmful effects from electric power and electrified railway lines, Vol. VII Protective Measures and Safety Precaution.

3.5 Interchange integration

3.5.1 Objectives

- 3.5.1.1 This section applies to stations that provide interchange facilities for passengers to transfer from one mode of transport to another, or between two services of the same mode.
- 3.5.1.2 Interchange or inter-modal integration should seek to achieve seamless connections between different transport modes to ensure passenger safety, enhance passenger convenience and reduce overall journey time.
- 3.5.1.3 The requirements covered in this section may be used as guidance when planning and designing interchanges.

3.5.2 Performance requirements

- 3.5.2.1 Interchange facilities should provide transfer between services that is efficient, easy, safe and equitable for all passengers.
- 3.5.2.2 Interchange facilities connecting rail services and other modes should:
- a) integrate transit stops (including bus and taxi) and interchanges into the design and layout of urban activity centres where possible;
 - b) provide direct routes to the interchange that allow high visibility and surveillance and provide public amenities along these routes where appropriate;
 - c) be direct and intuitive to minimise travel distances for the largest number of passengers;
 - d) provide shelter and weather protection;
 - e) minimise changes of level and be accessible and cater to people with special needs (PSN);
 - f) provide public transport waiting areas that allow clear views of train, tram or bus arrivals and departures;
 - g) ensure that lighting is well integrated with signage, interiors and landscaping in order to maximise safety and security;
 - h) provide current passenger information about services and the range of service timetables;
 - i) provide directional signage to platforms, stops, shops, parking and taxi ranks to minimise confusion;
 - j) avoid crossing gate lines;
 - k) allow passengers to benefit from having to purchase one ticket for the whole journey through a unified automatic fare collection system;
 - l) provide appropriate "Park and Ride" and private vehicle drop-off/pick-up facilities in strategic locations; and
 - m) accommodate current capacity and future growth.

3.5.2.3 The design and layout of an interchange zone should normally aim to give priority access to passengers:

- a) travelling on foot within the interchange;
- b) arriving at or leaving the interchange on foot;
- c) arriving at or leaving by bicycle;
- d) arriving at or leaving by taxi;
- e) being dropped off / picked up by private vehicles; and
- f) using the car park.

Inter-modal interchange analysis

3.5.2.4 For inter-modal interchanges, the type of information that should be analysed includes, but is not limited to, the following:

- a) number of services at peak, off-peak and late night;
- b) number of passengers per service;
- c) layover and dwell times;
- d) service accumulation; and
- e) set down/pick up requirements (bus stand or platform).

Individual transport interchange analysis

3.5.2.5 Each individual transport interchange mode should be analysed to establish:

- a) travel characteristics;
- b) incoming and outgoing passenger numbers at peak, off-peak and late night times;
- c) pedestrian circulation routes between interchange services, journey distance and time taken;
- d) transport circulation routes entering and exiting the interchange;
- e) frequency and timing of interchanging services; and
- f) timetable restrictions.

3.5.3 Design considerations

3.5.3.1 The profile of interchange activities should be analysed in detail to determine service patterns, dwell times, passenger and transport movements at peak, off-peak and late night periods.

3.5.3.2 The following design issues and constraints should be considered and analysed when designing interchange facilities:

- a) Location requirements:
 - i) external road layout may influence the direction of vehicle flow within the bus interchange;

- ii) location of trip destinations such as local shops, workplaces, educational institutions, etc., may determine pedestrian 'desire lines' (i.e. providing the most direct route reduces unpredictable pedestrian movements); and
 - iii) design of the interchange should allow for direct pedestrian routes whilst carefully locating pedestrian crossing points to maximise safety.
- b) Operational requirements:
- i) efficient movement of trams and buses to and from the interchange;
 - ii) bus layover space required;
 - iii) space for temporary parking or 'stacking' of terminating services;
 - iv) space for originating and through services to pick up passengers;
 - v) space for staff facilities (e.g. resting areas); and
 - vi) space for bicycle facilities (e.g. bicycle access paths and racks/storage).
- c) Passenger space requirements:
- i) for queuing, circulation, seating and any other facilities;
 - ii) passenger information regarding services arriving and departing from the interchange; and
 - iii) passenger barriers to control movements onto bus services.
- d) Nature of public transport traffic:
- i) number of public transport services per mode and per hour;
 - ii) number of separate routes; and
 - iii) configuration of buses, as appropriate (e.g. standard or articulated).

Urban and physical context

3.5.3.3 An integrated interchange should be developed on completion of a thorough site analysis. Critical aspects of this analysis should include the research and review of:

- a) land form;
- b) land use within walking distance;
- c) existing and future surrounding urban development including residential population, employment opportunities, retail and commercial facilities within the local community;
- d) adjacent land ownership;
- e) identification of future development opportunities;
- f) existing and proposed road network operation;
- g) street alignments;

- h) existing transport circulation routes including operational issues of each transport mode – overall route lengths and times, speed and manoeuvre restrictions; and
- i) bicycle routes servicing the area.

3.5.3.4 An integrated interchange should ensure that pedestrians are segregated from road vehicles including cars, taxis, buses and bicycles. Guard rails and glazed panels should be provided to ensure that pedestrians do not stray into the path of vehicles, and pedestrian crossings shall be clearly marked and afford priority to those travelling on foot.

3.5.3.5 Signal controlled pedestrian crossings should be considered if significant numbers of passengers are expected to cross a road to transfer between services.

Buses and trams

3.5.3.6 On street bus and tram stops should be located to:

- a) minimise walk distances to other services and modes;
- b) enable pedestrians to walk safely along natural desire lines; and
- c) minimise conflicts with other pedestrians where possible.

3.5.3.7 When passengers transfer to bus and tram services, a minimum level of provision should include:

- a) safe, comfortable and convenient walkways and waiting areas; and
- b) direction signing and information for other services and modes.

3.5.3.8 Bus terminal space should be enhanced and protected if there are to be many bus routes terminating at major interchange facilities. This is also true for other street-running modes, such as trams.

Taxis

3.5.3.9 Taxi station locations should be safe, adequately signed, well lit, and accessible.

3.5.3.10 The location of taxi stations should be clearly identified by the prescribed road markings and additional signage.

3.5.3.11 Taxis should not obstruct pedestrian routes and neither obstruct nor be obstructed by buses.

3.5.3.12 Taxi waiting areas should be weather protected.

Bicycles

3.5.3.13 Provision for bicycle parking racks at stations should be made to encourage healthy and environmentally friendly transport alternatives.

3.5.3.14 Bicycle racks should be installed in a convenient location near each station entry.

3.5.3.15 Bicycle racks should be located such that it does not conflict with regular pedestrian circulation. It is preferable that bicycle racks be:

- a) located externally, but undercover from direct sun and wind exposure;

- b) securely fixed through the pavement to the substrate;
- c) provided with an appropriate level of associated signage;
- d) located in open and well illuminated areas that fall under 'good passive surveillance';
and
- e) located so as not to obstruct traffic flows of either pedestrians or motor vehicles.

Private cars

- 3.5.3.16 The extent to which the private car is a necessary feeder mode to the interchange, particularly for passengers with special needs (PSN), should be assessed and provision and layout of car parking facilities should be allocated accordingly.
- 3.5.3.17 Parking spaces should not cater for local transport needs that are unrelated to the interchange.
- 3.5.3.18 Subject to location requirements, pick-up and drop-off points and/or short stay parking for people being picked up or dropped off at the interchange should be provided.
- 3.5.3.19 Priority use of parking facilities should be given to essential car users such as people with special needs.
- 3.5.3.20 Parking facilities and the access routes to/from them should be well lit, secure, clearly signed.
- 3.5.3.21 Access to parking facilities should be weather protected where practicable.

3.5.4 Shared interchange facilities

- 3.5.4.1 If an interchange facility is to be shared with the RTA, or any other future rail service provider, then the organisations involved should agree procedures for co-operating with each other through an Interchange Agreement that identifies all interfaces between all parties involved in managing and serving the interchange facility.
- 3.5.4.2 Scope of the Interchange Agreement will depend upon the scale and complexity of the individual interchange and should include:
 - a) arrangements for co-operation on the staffing of the interchange facility;
 - b) procedures for dealing with emergencies and service disruptions;
 - c) information and ticketing;
 - d) arrangements for cleaning and maintaining the interchange facility;
 - e) hours of operation and access rights; and
 - f) arrangements for providing passenger facilities at the interchange.
- 3.5.4.3 Where Developer and RTA buildings are physically linked to create an interchange facility, the following shall apply:
 - a) a uniformly consistent signage strategy to be used to facilitate passengers' wayfinding- refer to RTA's Signage Manual;

- b) system links between fire alarm systems to ensure that both parties are aware of a fire threat in either building;
- c) system links between PA systems for co-ordinated emergency evacuation messages;
- d) system links between CCTV systems to ensure that common areas and other key locations can be seen by staff in both organizations;
- e) system links between radio systems to ensure that staff and emergency services can communicate seamlessly when moving between buildings;
- f) operational agreements on evacuation procedures and maintenance of emergency exits where they may be shared between buildings;
- g) system links between Passenger Information Display (PID) systems to ensure that operational messages from one service provider may be displayed in areas managed by the other service provider – particularly for instances when the interchange facility must be suspended or service disruptions occur for any reason; and
- h) requirements for physical interfaces at facility perimeters including security, access, maintenance, airflow, fire compartmentation, noise and light pollution, etc., shall be coordinated.

3.5.4.4 To promote passenger convenience across Dubai, compatibility with RTA’s existing unified automatic fare collection system shall be required to permit the use of all connecting public transport services with a single common ticket (smart card).

3.5.4.5 PID systems are preferred to be consistent with RTA’s existing systems in terms of passenger information format and content in order to maintain quality of service across all stations and ensure passenger convenience through provision of real-time passenger information.

Level of service

3.5.4.6 Level of service should remain consistent as passengers pass between areas controlled by different authorities.

3.5.4.7 Wherever possible, the Developer and its appointed Designer should seek to ensure that architectural finishes are consistent throughout the interchange so that passengers do not experience change as they pass between areas controlled by different operators.

3.5.5 Interchange service requirements

Facilities for waiting passengers

3.5.5.1 Depending on passenger volumes, typical waiting times, and local conditions, provision of the following facilities should be considered:

- a) weather protection and air conditioning where appropriate;
- b) seating areas;
- c) public address and public information display systems;
- d) help points;

- e) telephones; and
- f) clocks.

3.5.5.2 Where shared waiting facilities are provided, they should ideally be located as close as possible to those services where the volume of waiting passengers and the time that they are likely to spend waiting is greatest.

Wayfinding and signage

- 3.5.5.3 Wayfinding should be simplified by using materials such as transparent materials to enable passengers to see the place that they wish to walk to and promote feelings of personal security.
- 3.5.5.4 The design of interchanges should ensure that, as far as possible, pedestrian routes are kept clear of structural elements to avoid obstruction of pedestrian routes which can cause delays and lead to congestion.
- 3.5.5.5 The main routes between the interchange facility and key passenger objectives, particularly other transport modes, should be clearly signed.
- 3.5.5.6 The entrance to the interchange facility itself should be highly visible to people arriving on foot and by other modes and people should be informed which modes serve the interchange facility before they enter it.
- 3.5.5.7 Routes connecting the points at which passengers board and alight from public transport services should be clearly and consistently identified.
- 3.5.5.8 Routes should be clearly signed to provide guidance and reassurance for passengers whenever they have to make a decision about which direction they should choose.
- 3.5.5.9 Signs should be legible in terms of their typeface and size, and should not be obscured by, for example, other signs or pieces of equipment.
- 3.5.5.10 Signs should follow a consistent hierarchy, providing more information about the upcoming mode or service as the passenger moves closer to it.
- 3.5.5.11 Signs should incorporate service 'branding' and internationally recognized symbols and pictograms. This will help where there are substantial flows of passengers who are unfamiliar with written English.

Ticketing

- 3.5.5.12 Where rail ticket offices and/or ticket vending machines are provided, these should sell tickets for all the services of different modes that serve the interchange wherever practicable.

Security considerations

- 3.5.5.13 All efforts should be made to ensure passengers are not concerned about personal safety and security.
- 3.5.5.14 Security of interchange facilities at railway stations and transport interchanges may be achieved by ensuring:

- a) manufactured materials are durable and resistant to heavy usage and attack by vandals and thieves;
- b) staff facilities are located such that staff can be seen by passengers
- c) transparent materials are used wherever possible;
- d) blind corners, recesses and other places where people can hide are designed out;
- e) pick-up and drop-off points are well lit and positioned in active locations where casual surveillance opportunities exist;
- f) walking and cycling links along routes are well lit and that surveillance opportunities are provided;
- g) services such as public telephones are placed where they are easy to find and where surveillance opportunities can be provided; and
- h) passengers can gather in designated areas where they can wait until their services become available, particularly in busy stations.

Emergencies and safety

- 3.5.5.15 Emergency and evacuation procedures and access rules should be agreed in advance with Dubai Police, Dubai Civil Defence, Dubai Corporation for Ambulance Service and should be tested as stipulated within the safety regulations that apply to the interchange.

3.6 Security

3.6.1 General

3.6.1.1 In addition to the overall security design requirements covered in section 2.7, the following particular requirements are provided as guidance that may help realise and reinforce the security strategy.

3.6.2 Rolling stock

3.6.2.1 Potential security risks may be reduced by, but not be limited to, the following measures:

- a) an open, partition-free interior environment that is well lit, allows visual continuity and enables monitoring by the staff attendant;
- b) CCTV equipment both internal and external to the vehicle with live streaming (when activated) to the vehicle operator and control centre;
- c) communications equipment allowing passengers to contact the vehicle operator and the control centre;
- d) audio and visual passenger information systems providing both live and pre-recorded security messages controllable from the vehicle operator and control centre; and
- e) alarm systems to the vehicle operator and control centre for cabinets containing vital systems and emergency equipment.

3.6.3 Stations

3.6.3.1 Potential security risks may be reduced by, but not be limited to, the following measures:

- a) the use of a transparent design incorporating a clean, open, bright and highly visible (both internal and external) environment;
- b) central monitoring of station systems;
- c) fire detection, alarm and suppression systems;
- d) CCTV equipment both internal and external to the station;
- e) communications equipment allowing passengers to contact the station operator or control centre;
- f) alarm systems to the station operator or control centre for cabinets containing vital systems and emergency equipment;
- g) intrusion alarm systems;
- h) access control and master key systems;
- i) cash management planning and systems;
- j) the provision for security control, screening facilities and associated spatial requirements;
- k) platform edge protection devices;

- l) audio and visual passenger information systems providing for pre-recorded security messages; and
- m) crowd control devices.

3.6.4 Rail system alignment including ancillary buildings

3.6.4.1 Potential security risks may be reduced by, but not be limited to the following measures:

- a) perimeter fencing or walls;
- b) CCTV equipment along perimeter fencing at all tunnel portals, exit points and risk sensitive areas;
- c) communications equipment allowing staff and passengers/members of the public to contact the control centre;
- d) alarm systems to the control centre for cabinets containing vital systems and emergency equipment;
- e) intrusion alarm systems catering to both persons and vehicles;
- f) access control and master key systems; and
- g) public address systems.

3.6.5 Depots and depot buildings

3.6.5.1 Potential security risks may be reduced by, but not be limited to, the following measures:

- a) the use of a transparent design incorporating a clean, open, bright and highly visible (both internal and external) environment;
- b) perimeter fencing or walls and crash barriers at depot entry points and around high risk ancillary buildings;
- c) CCTV equipment along perimeter fencing at all egress points both to the depot property and its facilities and risk sensitive areas;
- d) communications equipment allowing staff to contact the control centre;
- e) alarm systems to the control centre for cabinets containing vital systems and emergency equipment;
- f) intrusion alarm systems catering to both persons and vehicles;
- g) access control and master key systems;
- h) the provision for security control and screening facilities and areas; and
- i) public address systems.

3.6.6 IT security

3.6.6.1 Where appropriate, the reduction of potential security risks may be achieved by incorporation of, but not be limited to, the following measures:

- a) access control;

- b) password control;
- c) physical access and environmental control;
- d) IT operational control;
- e) change management control;
- f) disaster recovery;
- g) system hardening;
- h) secure network design;
- i) network segregation;
- j) use of perimeter firewalls;
- k) hardening of networking devices; and
- l) network monitoring.

3.7 Civil engineering

3.7.1 Introduction

- 3.7.1.1 Civil infrastructure should enable train services to be operated safely and reliably throughout the lifetime of the system.
- 3.7.1.2 Designs should be undertaken in accordance with latest international standards and best practice. This will ensure the infrastructure provided is appropriate in all respects.
- 3.7.1.3 The below requirements and principles are provided as guidance only for the design of civil infrastructure.

3.7.2 Key objectives and guiding principles

Safety

- 3.7.2.1 Safety should be the primary issue to be considered in the development of civil engineering designs.
- 3.7.2.2 Designs should be safe to build and safe in operation for public and staff. The safety of passengers and staff should be considered both in normal and emergency conditions including fire and emergency evacuation.
- 3.7.2.3 To ensure safety is achieved, a process of risk assessment should be used to identify risk and implement mitigation measures as described in section 2.3 on System Assurance.
- 3.7.2.4 Civil engineering designs should be fully integrated with architectural, building services and railway systems.

Aesthetics

- 3.7.2.5 The designs should provide an appealing, comfortable environment for the public to travel in, and for the operational staff to work in with a minimum standard of comfort equal to RTA's existing rail system.
- 3.7.2.6 Visible elements of the infrastructure, in particular station entrances and above ground structures should complement the Project's architectural design vision and as a minimum meet the design quality standards of RTA's existing rail system.

Durability

- 3.7.2.7 Durability of structures is a key issue in the harsh environment of Dubai. Designs should provide a high level of durability to resist the environmental conditions as well as the high passenger usage of a modern rail system- refer to section 3.2 for local design criteria.
- 3.7.2.8 Designs should be cost effective both to build and to operate over the whole life of the scheme.
- 3.7.2.9 Durable design should be achieved through attention to detail which allows high quality construction providing a high level of robustness and requiring minimum maintenance.

3.7.2.10 Materials and finishes should be specified in a manner that will ensure that they are fit for purpose and will give both durability and high quality in service appropriate to the particular conditions in Dubai in order to suggest a modern, safe, efficient and attractive facility.

Local context

3.7.2.11 Designs should be tailored to meet the cultural and environmental context of Dubai.

3.7.2.12 Designs should be tailored to meet the specific regulatory requirements of the relevant statutory authorities and other relevant parties as appropriate.

3.7.2.13 Design solutions should be appropriate for the ground and seismic design conditions,

3.7.2.14 Proven techniques should be promoted that minimise the risk to properties along and adjacent to the route during construction. In all cases, risks should be mitigated by ensuring appropriate site information is available and appropriate analysis undertaken.

3.7.2.15 Underground structures should be designed to resist uplift from ground water and allow safe dewatering during construction. Understanding the ground water regime, in particular the soil permeability, is a key design parameter.

3.7.2.16 Construction techniques should be considered in the design that limit the requirement for open work sites and allow fast reinstatement of the existing infrastructure to minimise the impact on members of the public.

3.7.3 Principle design requirements of civil engineering elements

3.7.3.1 Bridges, viaducts & elevated structures should:

- a) remain fit for the use required, and sustain all the actions and environmental influences likely to be imposed upon it – within acceptable deformation limits.
- b) accommodate existing and foreseeable requirements for users of the structure, equipment, services and plant.
- c) have adequate stability, resistance, stiffness, serviceability and durability.
- d) have sufficient resilience, robustness and structural redundancy to:
 - i) not suffer damage by accidents and events (such as vehicle impact, vandalism, and human error in design and use) that would be proportionate to the severity of their cause;
 - ii) have a low sensitivity to hazards that it might be subjected to; and
 - iii) so far as is reasonably practicable, provide adequate warning of collapse - for example, by showing signs of structural distress or deformation.
- e) have adequate clearance between rail traffic and the structure and between trains on adjacent tracks.
- f) be economic to construct, use and maintain.
- g) be readily accessible for routine examination and maintenance.
- h) have no unacceptable effect on;

- i) the safe use or performance of existing or proposed railway infrastructure and equipment;
 - ii) other infrastructure and equipment; and
 - iii) the safety of people using the structure, and the public at large.
- i) cause no damage to adjacent property and the environment.

3.7.3.2 Underground structures should:

- a) be of a design life appropriate to meet the function and performance requirements of the Project;
- b) meet the needs of the travelling public for safety, comfort and mobility and provide for the safe movement of people between public access and trains;
- c) take into account the following health and safety considerations:
 - i) the hazards and risks to persons constructing and maintaining the structure;
 - ii) measures which will protect workers if it is not possible to avoid or reduce the risk to a safe level; and
 - iii) the provision of adequate information on health and safety.
- d) be designed in consideration of the following:
 - i) short and long term structural stability;
 - ii) geometry and alignment to suit rail technology and operations;
 - iii) drainage requirements;
 - iv) fire and life safety;
 - v) ventilation requirements;
 - vi) movement joint details;
 - vii) impact on existing buildings and structures;
 - viii) methods of construction, temporary works requirements and construction sequence;
 - ix) ground conditions;
 - x) environmental and other local constraints; and
 - xi) mechanical and electrical services.

3.7.3.3 Buildings and ancillary structures should:

- a) maintain inherent structural integrity (support itself so as not to suffer complete or partial collapse);
- b) maintain the ability to carry without restriction any permitted applied static and dynamic design loads;
- c) maintain the planned design envelope and adequate clearance to permit the safe passage of rail vehicles;

- d) provide appropriate access and egress for all planned uses (including maintenance) and for reasonably anticipated emergency uses;
- e) sustain a condition and state so as not to cause unplanned interruption to, or restriction of, any aspect of the operating railway;
- f) minimise the likelihood and consequence of asset abuse. Asset abuse includes vandalism, planned/unplanned work, damage due to external event etc.;
- g) present an acceptable societal environmental impact (noise, vibrations, vegetation cover, adverse weather management etc);
- h) minimise environmental impact and demands at all stages in the lifecycle; this includes effects now and in the future, including successive refurbishment , final decommissioning and disposal routes;
- i) ensure safe operation to passengers, employees and members of the general public; and
- j) ensure safe ingress/egress by passengers, general public, employees and emergency services in planned & reasonably anticipated emergency scenarios.

3.7.3.4 Geotechnical design should:

- a) establish a ground model and a list of potential risks at an early stage through desk study and possibly preliminary investigation, this should include an assessment of likely hazards such as made ground and high water tables and any other known problems;
- b) use a model to inform the design of appropriate geotechnical and geo-environmental investigations, the aim of which is to confirm the ground model and establish the appropriate geotechnical parameters in a systematic way and hence provide geotechnical design parameters for the proposed works; and
- c) adopt a holistic approach to risk identification, ground investigation for geotechnical, geo-environmental and hydro geological aspects, consider seismicity and ensure that the work undertaken is appropriate to correctly inform the design and construction process.

3.8 Railway systems

3.8.1 Introduction

3.8.1.1 Rail systems should be tools designed to facilitate the work of the operator to deliver the required, high quality of service to the public.

3.8.1.2 Part of the quality of service measurement is the perception of safety and freedom from risk of injury.

3.8.1.3 The below requirements and principles are provided as guidance only for the design of rail systems.

3.8.2 Key guiding principles

3.8.2.1 Rail systems design should:

- a) ensure that materials, systems, sub-systems and components are specified in a manner that will ensure that they are fit for purpose and will give both durability and high availability in service in the particular environmental conditions in Dubai;
- b) include specific requirements for reliability and maintainability to ensure that service disruptions are avoided and long-term maintenance costs are optimized;
- c) allow and encourage the use of modern technology where this is advantageous to the Operator. Technical requirements will be based on international best practice by reference to standards that are internationally recognised as applicable;
- d) incorporate the requirement to integrate railway systems design, where appropriate, with the architectural design vision and the overall identity of Dubai public transport. The design of passenger interfaces and visible elements of railway systems, particularly the rolling stock, will be developed to complement this overall design vision;
- e) be tailored to meet the specific regulatory requirements of Dubai and incorporate the requirements of statutory authorities and other relevant parties as appropriate.
- f) be tailored to meet the cultural and environmental context of Dubai; and
- g) include requirements that are necessary and sufficient to ensure that the delivered products meet the objectives of the Developer Guidelines.

3.8.3 Principle design requirements of rail systems elements

3.8.3.1 Trackwork should:

- a) provide a safe and comfortable passenger ride;
- b) withstand the high temperatures and temperature ranges experienced in Dubai;
- c) address the dust and sand accumulation;
- d) be coordinated with the rolling stock design to minimise long-term maintenance costs; and

- e) be coordinated with civil engineering design to ensure that targets for noise levels can be achieved.

3.8.3.2 Rolling Stock should:

- a) have high levels of safety built into the design to provide protection in the event of fire and/or collision with independent evacuation of rolling stock possible in the event of an emergency;
- b) eliminate failures which will prevent a train from moving under its own power through provision of redundant systems or bypass commands;
- c) minimise power consumption and have minimal impact on the environment, in particular air and noise pollution;
- d) deliver performance in the harsh environment of Dubai and propulsion and braking tailored to provide a consistent operating service at the level of service expected;
- e) provide a comfortable passenger ride in a well illuminated, air conditioned environment;
- f) deliver to the highest reliability and ease of maintenance;
- g) be aesthetically appealing on the interior and exterior design;
- h) provide seating and interior finishing appropriate to the type and class of service being provided including dedicated facilities for women passengers; and
- i) encourage creativity in the interior design of rolling stock that will integrate with the overall design vision and identity of Dubai public transport.

3.8.3.3 Power Supply should:

- a) ensure that the effect of any single, credible failure on the quality of service offered to the passengers both in terms of the transport service and the station environments, is minimised as far as practicable through redundancy and graceful degradation of power supply;
- b) allow for future upgrade and expansion;
- c) be coordinated with the operational requirements and control facilities to ensure that failures and system faults can be rapidly detected, located, isolated and mitigated to minimize the impact on passenger service and minimise associated hazards;
- d) ensure automatic recovery processes are implemented where appropriate to minimise the effect of failures;
- e) incorporate robust measures and arrangements for electrical, mechanical and physical safety that minimise and, where reasonably practicable, eliminate hazards for passengers, public, and operatives;
- f) afford resilience, in terms of system provisions and constituent equipment, to operate under all credible local environmental and climatic conditions;
- g) achieve an energy efficient total system configuration with the potential for optimised system operation;

- h) provide flexibility in accommodating and interfacing with the characteristics of trains and other (non-traction power) users/loads;
- i) minimise the level of electromagnetic aggression at all interfaces (conducted, radiated, etc.);
- j) facilitate the introduction and application of new/emerging technologies (e.g. smart grid), and new/emerging approaches to power system configuration and voltage levels;
- k) promote the use of overhead electrification systems by reducing the visual impact and stressing the security and reliability of overhead contact system assemblies using simplified and standardised assemblies with secured and robust connecting joints;
- l) consider buildability as a major factor in the design of power supply and overhead contact systems; and
- m) use remote condition monitoring to facilitate maintenance and enable routine maintenance of the system during non-passenger operation.

3.8.3.4 Railway Control Facilities should:

- a) eliminate the risk of human error by being based on a study of the operational tasks to be performed at the control centre and provide information, control and communication functions in an integrated operating environment to simplify the tasks of operational staff;
- b) configure railway control systems with a high level of redundancy such that no single failure will cause a loss of service to the public;
- c) build-in system fault detection and diagnosis such that precise information is immediately reported to the operations and maintenance staff to permit prompt and effective restoration of full functionality; and
- d) ensure that back-up control facilities are available for all systems integrated through the railway control facilities and that a strict hierarchy of control is enforced.

3.8.3.5 Automatic Fare Collection systems should:

- a) be compatible with existing Unified AFC fare media to permit the use of all connecting public transport services with a single common ticket (smart card);
- b) allow easy future upgrade and expansion;
- c) be flexible enough to allow the addition of equipment to meet increased passenger demand during short term periods (e.g. special events);
- d) be user-friendly with single unified signage and MMI messages;
- e) be aesthetically appealing and blend in harmoniously with the station architectural theme;
- f) allow the introduction of new technologies;
- g) have higher configuration capabilities;
- h) accommodate all passenger types (including special needs passengers);

- i) provide self-service fare media sales, top up and validation equipment;
- j) have built-in fault detection and diagnosis such that precise information is immediately reported to the operations and maintenance staff to permit prompt and effective restoration of full functionality;
- k) provide access control and payment of parking charges for Park & Ride facilities integrated with the associated station AFC system;
- l) be coordinated with the user interface design and the general appearance of visible equipment and station signage;
- m) provide options for both open and closed systems and for different methods of validation and deduction of fares; and
- n) provide interface with Controlled Access Security Systems so that employees can use the same card for access and travel.

3.8.3.6 Platform Screen Doors should:

- a) be designed so that evacuation to the platform shall be possible under any scenario where the train is misaligned with the platform screen doors;
- b) have a high level of safety and protection;
- c) have the highest level of cooling containment to minimize cooling leak during opening and closing of doors;
- d) allow easy and smooth access to all various special needs passengers;
- e) have a high reliability and provide local control to minimise passenger inconvenience in the event of a fault; and
- f) be coordinated with the station design.

3.8.3.7 Building Services should:

- a) be configured to provide high availability and easy maintenance;
- b) perform in the harsh environment of Dubai;
- c) be coordinated with the fire strategy and environmental control requirements;
- d) be fully integrated with rail control systems; and
- e) have high safety and monitoring capabilities, especially under the emergency/ degraded operation conditions.

3.8.3.8 Depot Facilities should:

- a) be specified to meet the requirements of the rolling stock and fixed systems forming part of the Project;
- b) be specified with equipment and layouts based on workflows such that material handling and the movement of bogies and wheelsets within the workshops is minimised;
- c) minimize noise and vibration, if located within residential areas;

- d) have equipment provided for ease of use and, where practicable, linked directly to a computerised maintenance management system to automate record keeping;
- e) contain equipment to facilitate maintenance and minimise the size of the maintenance workforce required;
- f) have environmentally controlled storage facilities, where required, to protect spares from deterioration under the ambient conditions in Dubai; and
- g) be aesthetically appealing buildings.

Appendix 1

Earthing and bonding arrangements

A1 Appendix 1: Earthing and bonding arrangements

A1.1 General

1.1.1.1 Appendix 1 covers particular requirements and supplementary information pertaining to earthing and bonding which are provided for the purpose of guidance. This appendix should be read in conjunction with sections 2.5 and 3.4.

A1.2 Categories of earthing

1.2.1 General

1.2.1.1 The earth electrode system provided at any location may be common to two or more categories of earthing, in which case all the earthing points on the individual items of equipment should be bonded together and any earth fault currents should not enter the general body of the earth.

1.2.1.2 In general, earthing and bonding is required under one or more of the categories described below.

1.2.2 Neutral earthing

1.2.2.1 Connection to earth at one or more nominally equipotential points of the current-carrying conductors of each section of the power supply system should be arranged to ensure that the voltage at any point in the system relative to the general body of the earth is within definite limits, and provides a low impedance path for earth fault return currents.

1.2.2.2 For low impedance earth paths to be established the ground conditions should first be measured (soil resistivity Ω/m) and the system designed according to the results. Conditions may vary throughout the year due to seasonal weather.

1.2.3 Protective earthing

1.2.3.1 Connection to earth at one or more points which are not current-carrying parts of electrical equipment should be arranged to ensure that, in the event of a failure of insulation or other inadvertent connection between current and non-current-carrying parts, no dangerous potential difference occurs between the non-current-carrying parts of the equipment and the general body of the earth or adjacent equipment.

1.2.3.2 Protective earthing should provide a low impedance path for earth fault current.

1.2.4 Adjacent metallic structures

1.2.4.1 Metallic structures, which are not part of the electrical equipment but are in close proximity to the electrical system, may also need to be earthed.

1.2.5 Mitigation of interference effects

- 1.2.5.1 The connection to earth of the screening conductors of any light current signal and control cables should be confined to one end in order to avoid circulating currents in the screen causing interference on the signal cores. There may be exceptions to this and the solution to be adopted in individual cases should be determined in accordance with EMC considerations.
- 1.2.5.2 There should be no exceptions in the case of screened or armoured cables to the DC switchgear which shall have the enclosures on insulators and connected to the substation earth through an earth fault detection shunt (frame fault detecting device).

1.2.6 Unearthed systems

- 1.2.6.1 No part of an unearthed system where the current-carrying conductors are fully insulated from earth at all points should be automatically disconnected on the occurrence of a single earth fault in that part.

1.2.7 DC traction negative return system

- 1.2.7.1 The DC negative return traction system, where the running rails form the return conductor, should not be permanently connected to earth except for the rails within the depot workshops which are non-electrified and should be permanently connected to earth but insulated from the rest of the return system.
- 1.2.7.2 The degree of insulation between the rails and the general body of the earth is necessarily a compromise between the need to control step and touch voltages, and the need to limit stray current leakage. A significant proportion of the return current may leave the rails and return through the ground to the vicinity of a substation before returning to the rails and hence to the rectifier negative pole.
- 1.2.7.3 Railways exposed to varying atmospheric conditions should take into account the large range of humidity levels expected.

1.2.8 AC traction power return system

- 1.2.8.1 The AC traction power return system should consist of running rails, impedance bonds, crossbonds, overhead static wires and ground.
- 1.2.8.2 The system should be designed to provide a low impedance path for the return currents to a traction substation under normal and fault conditions and to limit rail-to-ground voltages to a safe value.
- 1.2.8.3 The running rails should be connected in parallel with each other at impedance bond locations and connected to the running rails of adjacent tracks in parallel by using crossbonds and should be connected to the overhead static wire.
- 1.2.8.4 Return current ground buses should be connected to rails through impedance bonds and to the substation earth farm.

- 1.2.8.5 Crossbonds should be provided to parallel all rails at all traction substations, autotransformers and switching stations and should be connected to the earthing system and neutral point of the transformer and autotransformer (for autotransformer systems).
- 1.2.8.6 Location of impedance bonds and crossbonds should be coordinated with the signal designer.
- 1.2.8.7 All rail joints, crossovers, turnouts, and expansion joints should be provided with rail bonds.
- 1.2.8.8 Impedance bonds should also be provided to connect all track rails to the platform grounding system at all passenger stations to equalise potentials from trains.

1.2.9 Earthing for lightning protection

- 1.2.9.1 Protection of buildings and structures against the effects of lightning should be provided through the use of lightning air terminal, down conductors and an earth electrode system.
- 1.2.9.2 Account should be taken of the locality and lightning incidence rate and applied to the protection of the Project as a whole from “Far” and “Near” strikes, individual structures and personnel protection.

A1.3 General earthing requirements

1.3.1 Treatment of AC power supplies

- 1.3.1.1 An earth farm should be provided for the services substations and at other locations as required for the purposes of earthing AC power supply systems under the category of Natural Earthing and metallic enclosures and structures under the category of Protective Earthing and Adjacent Metallic Structures.
- 1.3.1.2 Earth farms at each substation and other locations should be multiple-interconnected by bonding connections, cable sheaths, cable armouring, to adjacent earth farms to form an incidental earth mat embracing the whole of the Project.
- 1.3.1.3 The armouring of incoming HV power supply cables from DEWA should not be connected to the receiving substation earthing system. However, there should be provision to do so conveniently on a temporary basis whilst temporary work and testing is carried out.
- 1.3.1.4 It shall be recognised that such an interconnection of the earth systems may encourage the flow of stray DC traction currents through the ac earth systems, which could lead to corrosion of earth electrodes.
- 1.3.1.5 The alternative solution of segregating the Project earth farm and its associated earthing system from DEWA earth farms and earthing systems may be difficult to implement and to maintain. Although segregation should tend to discourage the flow of stray DC traction currents through the earthing systems, this will not necessarily decrease the corrosion of particular electrodes, and may well encourage stray currents to pass from one buried structure to another buried structure, leading to corrosion of the structures. Two other difficulties could arise with segregation as follows:

- a) transferred potentials will appear across insulated joints used to segregate the systems where there are interconnecting cables, etc. and between adjacent structures bonded to different earthing systems; and
- b) provision of earthing for the screening of telecommunications cables to reduce interference.

1.3.1.6 For the reasons described above, the effects of the segregation should be monitored closely.

1.3.2 Treatment of DC traction supplies

1.3.2.1 DC traction supply systems for the main line and depot (excluding the depot workshop) form two entirely separate systems in so far as they are not normally interconnected with any earth electrodes or earthing systems discussed above.

1.3.2.2 The earthing and bonding of traction systems are described under 'DC traction negative return system' above.

1.3.2.3 The running rails of the main line and depot and hence DC negative busbars should be separated by insulated rail joints at the depot entrance.

1.3.2.4 Enclosures that are an integral part of the DC traction system should be insulated from the ground and bonded directly to the running rails. Certain structures (e.g. trackside isolator cabinets and signalling equipment) in close proximity to the track, but that cannot be insulated from the ground, should be bonded to the track system via devices that are only effective for traction fault currents or currents flowing into the track (e.g. voltage limiting devices (VLDs)).

1.3.2.5 Because the DC traction system is not bonded to any earth electrodes, the track and any structures bonded thereto may be at a potential relative to the earthing system and any structures bonded thereto. Provisions for separating or screening the two systems should be made or the use of special devices (e.g. VLD's) incorporated to give limited interconnection between the systems where they are in close proximity.

1.3.2.6 The exception to the above is the DC traction return system within the depot workshops which should be insulated from the main line return system, fed from a dedicated rectifier and deliberately earthed to the depot earthing system. Hence, within this workshop area, metalwork adjacent to the vehicles should be bonded directly to the local traction return / earth system, without insulation from earth.

1.3.3 Treatment of unearthed auxiliary supplies

1.3.3.1 Certain low voltage auxiliary, signalling, control or indication systems come under the category of 'Unearthed Systems' where the ability to temporarily continue in operation with a single earth fault gives increased security of supply.

1.3.3.2 Earth fault or earth leakage detectors should be provided for circuits in this category in those cases where it is essential to rectify the fault as soon as possible to avoid the incorrect operation of safety signalling or the disconnection of essential supplies due to the occurrence of a second earth fault.

1.3.4 Lightning protection

1.3.4.1 The protection of above ground structures from lightning under the category of section 1.6.4 below is included within this document.

A1.4 Earthing of power supply systems

1.4.1 Supplies

1.4.1.1 The electrical power supply systems may comprise:

- a) 132kV, 69kV, 33kV, 22kV, 11kV and 380V 3 phase, 3 and 4 wire AC supplies;
- b) 220V and 110V 1 phase, 2 wire AC supplies at 50Hz;
- c) 25kV single phase traction supplies;
- d) 1500V and 750V DC traction supplies; and
- e) 110V DC control supplies.

1.4.2 Earth electrodes and earthing systems

Earthing systems for receiving substations

1.4.2.1 Each receiving substation should be provided with earth farms for both DEWA and the Project.

1.4.2.2 Connections to the earth farms should be through two 'Principal Connections' links by means of stranded insulated copper cables with a minimum cross-section area calculated for the worst case conditions of earth currents through marshalling earth bars in the area of the farms.

1.4.2.3 Each of the earth rods should be connected to each of the marshalling earth bars by single, stranded, bare copper cables with appropriate cross-section area.

Earthing systems for underground substations

1.4.2.4 Each service substation should be provided with an earth farm, of resistance less than 1 ohm, and connected to the substation earthing system through two 'Principal Connection' links by means of stranded insulated copper cables with a minimum cross-sectional area calculated for the worst case conditions of earth currents.

1.4.2.5 The substation earthing system should be compliant with IEC 60364 and IEC 61312.

1.4.2.6 Traction DC switchboards should be fitted with low-impedance earth fault protection equipment (with the exception of the depot workshop feeder). Hence, only the manufacturer's nominated earthing terminal should be connected to the substation earthing system and all other metallic earthing connections should be avoided.

Earthing for distribution systems

1.4.2.7 Supplies at 380/220V AC, or 110V AC should be made available for depot and station equipment and, where applicable, trackside equipment.

- 1.4.2.8 These supplies should be derived from 380V AC star-connected 3-phase supplies, the star point of which should be bonded to the services substation earthing system. Continuity of this earth connection to the point of supply should be provided by the cable sheath / armouring.
- 1.4.2.9 All locations receiving such supplies, which are remote from the earth system of any traction or distribution substation, should be earthed by one of the following methods:
- a) low impedance connection to the trunk earth system such that the minimum earth fault current is adequate to operate the overcurrent protection in accordance with IEC 60364;
 - b) where the requirement in (a) cannot be met, approved earth leakage protection should be provided,
 - c) by connection of the earth terminal to the earth electrodes at any adjacent location via cable sheaths and armouring, such that the earthing impedance meets the requirement in (a) above; and
 - d) by connection of the earth terminal via sheaths and armouring of the supply cables or other bonding conductor to the earth system of the services substation, such that the earth fault loop is entirely metallic and of sufficiently low impedance to meet the requirement of (a) above.
- 1.4.2.10 The earthing of all distribution and sub-distribution systems should be in accordance with IEC 60364.

1.4.3 System earthing

General

- 1.4.3.1 System Earthing' describes the connection to earth of the neutral or negative, nominally equipotential points of the current-carrying conductors in each section of the power supply system.
- 1.4.3.2 The main line DC traction negative return system, including the track itself where used as part of the negative return, should be separately interconnected and bonded and not deliberately earthed at any point. It is essential that this DC system and all AC earthing systems should be separated from one another, except where bonded together in a specific and controlled manner.

132kV AC supplies

- 1.4.3.3 The method of earthing of 132kV, 3 phase supplies from DEWA should be coordinated with DEWA.

33kV and 22kV AC supplies

- 1.4.3.4 The star point of the 33kV and 22kV, 3 phase, 3 wire secondary winding of the step down transformer should be connected to the substation earthing system via a resistor, or other impedance device, to limit the earth fault current to a value compatible with the system earthing resistance.

380V AC supplies

- 1.4.3.5 The star point of the 380V secondary winding of the services transformer should be connected to the protected earth bar of the 380V AC switchboard. The protected earth bar should be connected to the neutral bar via a neutral link in the switchboard. The neutral bar of the transformer should be solidly earthed, via a bolted link to the earthing system.

220V AC supplies

- 1.4.3.6 The 220V AC supplies should be taken from one phase and the neutral of the above 380V AC supplies. The neutral should be earthed in accordance with clause 1.4.3.5 above.

110V AC supplies

- 1.4.3.7 The 110V AC supplies should be obtained from 220/110V AC transformers. Each 110V AC winding of these transformers should be fitted with a centre tap which should be solidly earthed. Approved earth fault detection equipment should be provided.

750V DC traction supplies

- 1.4.3.8 The 750V DC main line system negative pole should not be connected directly to earth, whereas the depot workshop negative pole (with dedicated rectifier) should be deliberately earthed at the workshop. The negative terminal of the dedicated rectifier should have a voltage limiting device connected between it and the substation earth system.

110V DC supplies

- 1.4.3.9 Both poles of the 110V DC battery supplies used in traction and distribution substations and elsewhere in connection with the power supply system should be insulated from earth.
- 1.4.3.10 Approved positive and negative earth fault detection equipment shall be provided.

1.4.4 Equipment earthing (not-trackside)

General

- 1.4.4.1 This section refers to the treatment of metal enclosures or supporting metalwork for the equipment associated with the power supply systems covered under 'Earth electrodes and earthing systems' mentioned above, with the exception of the trackside equipment which is covered in the 'Track and trackside equipment' section below.
- 1.4.4.2 Earthing and bonding of electrical equipment is required to reduce the effects of interference, and to ensure the personal safety of the public, operational and maintenance staff. Where there is a conflict between these requirements, personal safety shall always take precedence.

33kV and 22kV cables

- 1.4.4.3 The earthing of screens and armouring of all 33kV and 22kV cables shall be earthed at both ends. Exception may be made at the extreme ends of the system to avoid any circulating currents detected in service.

- 1.4.4.4 Means should be provided for disconnecting the screen ends, individually, from earth for testing purposes.

750V DC and 1500V DC cables

- 1.4.4.5 750V and 1500V DC cables do not have any metallic sheath or armouring, but should be double-insulated. Where cleats, conduits or ducts are used with such cables, they should be in non-metallic material. Positive and negative DC traction cables should be run in separate ducts from each other, and kept physically separate wherever practicable.

Other power supply cables

- 1.4.4.6 This section covers the cables for the distribution of 380/220V AC supplies and 110V DC supplies.
- 1.4.4.7 The armouring of multicore armoured cables should be earthed at both ends via an earth terminal provided with the gland, or via the metalwork of the cable box and structure to the earth bar or terminal of the equipment at which the cable is terminated.
- 1.4.4.8 Exceptions may be where the equipment at each end does not share the same earth system. For example, the DC switchgear for which the enclosures should be insulated from the substation earth and connected to it via a leakage current measuring shunt. In this case the armouring should be earthed only at the distribution board end.
- 1.4.4.9 Single core cables should be earthed in a similar manner but at one end only.

132kV, 33kV and 22kV AC switchgear

- 1.4.4.10 All AC switchgear should be earthed directly to the substation earthing system.

750V and 1500V DC switchgear

- 1.4.4.11 Each 750V and 1500V DC switchboard should be fitted with an earth bar running the full length of the switchboard and all components of the metal-clad enclosures should be bonded to the internal earth bar. The circuit breaker trucks themselves should be fitted with scraping contacts to provide the necessary earthing connections. The whole switchboard including earth bar should be insulated from ground and the earth bar of the switchboard connected to the substation earth bar via a DC shunt for leakage current measuring.
- 1.4.4.12 Each 750V and 1500V DC switchboard should be fitted with low-impedance earth fault protection equipment combined with an inter-tripping scheme, incorporating a current-measuring device around the single connection to the substation earth connection. The scheme should be arranged to initiate a local mass trip of all DC and associated AC circuit breakers and to inter-trip corresponding DC feeder breakers at adjacent substations. In order to ensure correct operation, only the manufacturer's nominated earthing terminal should be connected to the substation earthing system. All other metallic earthing connections, including fortuitous connections such as cable trays and armouring, should be avoided.

- 1.4.4.13 The depot workshop DC switchgear panel should form a separate DC switchboard with the negative earthed in accordance with clause 1.4.3.8.

380V, 220V and 110 V AC switchgear

- 1.4.4.14 All metallic components of the cubicles should be bonded to an earth bar which should be connected to the substation earth system.

Battery equipment

- 1.4.4.15 All metallic components of metal stands and cubicles for batteries, battery chargers and DC distribution switchboards should be bonded to an earth bar which should be connected to the earth system.

Transformer & rectifiers

- 1.4.4.16 All electrically separate parts of each transformer core should be bonded together and the core as a whole should be insulated from the enclosure/tank. An accessible removable link should be provided between the core and the enclosure/tank for earthing the core for core testing.
- 1.4.4.17 All metallic components of control compartments should be bonded to an earth terminal or bar, which should be connected to the enclosure. The enclosure should be connected to the substation earth system with a suitable fault rated earth connection.
- 1.4.4.18 All metallic components of the Traction Rectifier should be bonded to an earth terminal or bar, which should be connected to the rectifier enclosure. The enclosure should be connected to the substation earth system with a suitable fault rated earth connection.

33kV/380V and 22kV/380V services transformers

- 1.4.4.19 All electrically separate parts of the core should be bonded together, and the core as a whole should be insulated from the remainder of the transformer and its enclosure/tank. An accessible, removable link should be provided between the core and the enclosure/tank. All other parts of the transformer and its enclosure should be connected to the substation earthing system with a suitable fault rated earth connection.

380/220V and 110V transformers

- 1.4.4.20 Each transformer should be provided with a screen between the primary and secondary windings so that in the event of a fault the primary winding or its connections cannot be connected to the secondary winding or its connections. The centre point of the secondary 220V or 110V winding should be connected to the substation earthing system.
- 1.4.4.21 This screen, the core and framework of each transformer should be connected to the earth bar or terminal of the enclosure in which the transformer is located. The earth bar or terminal of the enclosure should be connected to the substation earthing system.

Marshalling panels

- 1.4.4.22 All metallic components of each cubicle should be bonded to an earth terminal or bar, which should be connected to the earthing system.

Negative busbars (750V and 1500V DC traction systems)

- 1.4.4.23 A negative busbar, insulated from earth and mounted within a sheet steel enclosure, should be provided at each main line traction substation for the purpose of providing a connection point for all rectifier negative cables and outgoing negative feeder cables to the track.
- 1.4.4.24 The structural and other metallic parts of the enclosures for each negative busbar should be bonded to an earth terminal, which should be connected to the substation earthing system. The negative busbars should be connected to the substation earth system by an approved voltage limiting device (VLD or FNAGS).

Instruments, relays, control switches and other electrical components

- 1.4.4.25 All metallic cases and/or frames of instruments, relays, control switches and other electrical components mounted on control panels or in cubicles should be connected to the earth bar or terminals of the cubicle in which the component is mounted.

Ancillary equipment

- 1.4.4.26 Cubicles, cabinets, racks and panels should be provided with a copper earth bar, complete with a disconnectable testing link with a suitable cross-sectional area for the possible fault current, placed at a convenient position within the equipment. All metal parts, other than those forming part of an electrical circuit, should be earthed by connection to the earth bar.
- 1.4.4.27 When apparatus or instruments are accommodated on panel cubicle doors or swinging frames, flexible cable or braid should be used for earthing these items; the door hinges should not be acceptable as means of earthing this part of the equipment.
- 1.4.4.28 Except where otherwise approved, a stud type terminal of diameter not less than 12mm, or a tapped boss of equivalent size, should be provided on the outside of each cubicle or structure for the purpose of making the connection to earth. This terminal should be connected to the substation earthing system.

1.4.5 Track and trackside equipment

DC traction return running rails (main lines)

- 1.4.5.1 The running rails, where used for DC traction return purposes in main line and depot areas outside the workshop, should be free of any direct connection to earth or earthed structures.
- 1.4.5.2 As the rail transit system uses the train wheels and running rails for the DC traction current return circuit, the rails should have volt drop along them as a result of the flow of traction current. The rails are imperfectly insulated from earth or the structures on which they are fixed and therefore a circuit parallel to the rails can occur by means of which current driven by the volt drop flows out of and back into the rails. The current, which flows out of the rails and returns at some other point, is referred to as stray current.
- 1.4.5.3 The most serious effect of the stray current is electrolytic corrosion at the point where current flows out of a metal surface into concrete or soil. A cell is set up at the interface,

the potential of which varies with the materials present. For corrosion to take place the interface potential must exceed the potential of the cell.

- 1.4.5.4 The rails forming the intentional return current path should be nominally insulated from earth in order to discourage stray earth currents.
- 1.4.5.5 A system should be provided for monitoring and controlling the level of stray currents which nonetheless may flow into and out of under-track metallic structures, such as reinforcing bars or mesh within track slabs.
- 1.4.5.6 This system should allow for nominated metalwork to be bonded together and connected to an along-track stray current collection cable. These cables should be connected to local and substation test points. The system, depending on the configuration of connections at the test points, can act as a local stray current collection and return facility, or as a test facility.
- 1.4.5.7 All main line rails should be nominally insulated from earth, through the use of insulating components. The nominal insulation level should be maintained over the designed life when subject to environmental operating conditions such as debris and the products of operation. Acceptable minimum values for insulation (in terms of conductance per metre) for various track forms should be as specified in Table 1 of EN 50122-2.
- 1.4.5.8 The insulation level between earth (or the under-track stray current collector mats, where provided) and the rails should be no less than $10\Omega/\text{km}$ for tunnel and $2\Omega/\text{km}$ for open air of single track (based on two running rails per track) under normal operating conditions.
- 1.4.5.9 The insulation level of each section should be tested, on completion of the track works for the section, and the results recorded. The commissioning acceptance value should be $100\Omega/\text{km}$. Values less than this but of the same order may be accepted under exceptional conditions. In all cases the track to earth resistance should be assured at $10\Omega/\text{km}$ ($2\Omega/\text{km}$ for open air) over the life of the track insulation.
- 1.4.5.10 The above track insulation level should be maintained through points and crossing work including the depot stabling area.
- 1.4.5.11 The track insulation should be of the 'double insulation' type and a nominal creepage distance of 10mm of hydrophobic surface should be provided. The insulation test should be repeated as part of the diagnostic procedure for the mitigation of stray current effects.
- 1.4.5.12 Both running rails per track on the Main Line and at least one running rail per track in the depot should be used for DC traction return purposes, and cross-bonded to other tracks as described below.
- 1.4.5.13 Each DC traction return rail should be electrically bonded longitudinally at each joint (other than welded joints), except where insulated joints are required for segregation between running lines, depot, depot/workshop building tracks or for segregation from non-electrified tracks.
- 1.4.5.14 These continuity bonds and bonds across expansion joints and discontinuities such as insulated rail joints provided for track insulation testing should be in duplicate and fully rated for the anticipated DC traction return currents.

DC traction return running rails (depot workshop)

- 1.4.5.15 The DC negative return rails for the depot workshop should be electrically isolated from those in other areas of the depot and on the rest of the system by means of insulated rail joints outside the building to ensure that any stray currents due to the unavoidable earthing of the Workshop track are closely contained in its geographical area, and not propagated to the main traction return system.
- 1.4.5.16 The above arrangement also simplifies the AC/DC protection and touch potential limitation arrangements. Hence, only within the Workshop area, the AC and DC earthing systems intentionally interconnected.
- 1.4.5.17 Within the depot workshop area, metalwork, which is in close proximity to shore leads, down shop conductors and shoe gear, should be electrically continuous and bonded to the traction return rail and hence earth.

750V and 1500V DC isolators

- 1.4.5.18 The metal-clad enclosures for the 750V and 1500V DC main line isolators should be provided with a substantial, stainless steel stud terminal to which all parts of the enclosure, internal and external supporting steelwork and metal parts of the operating handle should be bonded.
- 1.4.5.19 The metal clad enclosure should be bonded by, fault rated, bonding cable, to the 'trunk earth' cable or 'structure earth' where one is provided, which should have a controlled touch potential as described in clause 1.4.5.25 below. Where no trunk earth cable or structure earth is accessible within 4 metres, the enclosure should be insulated from earth and bonded to the nearest running rail.
- 1.4.5.20 Some 750V and 1500V DC isolators may be motorised, using an LV AC power supply and controlled over the SCADA system.
- 1.4.5.21 The sheath of the LV AC supply cable should not be connected to any part of the isolator cabinet.
- 1.4.5.22 The DC multicore control cable sheath should not be connected to any part of the isolator cabinet.
- 1.4.5.23 The isolator cabinet should be connected to the trunk earth cable as for any other trackside isolator cabinet.
- 1.4.5.24 The incoming LV AC supply should be segregated from the general body of the cabinet and equipment in the cabinet by means of an isolating transformer.

Clearance to earthed equipment or structures

- 1.4.5.25 No part of any structure or other equipment, which is connected to an earth system, should be closer than 2.5m from the main line, or depot yard return rail, or any part of any equipment solidly bonded to the main line, or depot yard, traction return rail, or the vehicle static envelope, without providing protection against dangerous step potential. Examples of such equipment are; sump pumps, lighting, metallic walkways, and the bare trunk copper earthing cable.

- 1.4.5.26 Where this separation cannot be met owing to limitations of trackside space the provisions of sub-section A1.6 below for earthed metallic structures within 2.5m of the vehicle static envelope should apply. To meet the provisions of sub-section A1.6 the bare trunk earth cable should be connected to the running rails at strategic chainages through voltage limiting devices (VLD's). The touch potential of the trunk earth being controlled in this way the metal enclosures of all the above equipment within the 2.5m limit should be bonded to the trunk earth cable.
- 1.4.5.27 Platform screen doors on station platforms should be bonded to the track by duplicate insulated cables and insulated from the general body of earth.
- 1.4.5.28 Metal enclosed electrical equipment within 2.5m of the screens should not be earthed but the enclosed live equipment should be 'double insulated' from the enclosure.
- 1.4.5.29 The station platform surface in the vicinity of the platform screen doors should be of insulating material.

Earth wire for OCS system

- 1.4.5.30 An earth wire, or overhead static wire, should be installed in parallel to the overhead line cable of the Overhead Catenary System (OCS) and be as a common earth wire to distribute the continuous path of normal and fault return current.
- 1.4.5.31 Earth wire size should be designed to limit the potential rise due to fault currents in accordance with EN 50122-1 and should connect to all non-live parts of OCS equipment.
- 1.4.5.32 Earth wire and return conductor should be periodically connected to the running rails via impedance bonds as necessary.
- 1.4.5.33 Structures and supports in the depot area should be bonded directly to the traction return.

A1.5 Earthing of communication and control systems

1.5.1 General

- 1.5.1.1 There are several separate sub-systems which collectively form the control and communications system. Equipment, enclosures and mountings associated with these sub-systems should be distributed throughout the Project at trackside, stations and depot locations.
- 1.5.1.2 The equipment, enclosures and mountings associated with the control and communications system are generally not anticipated to be located within 2.5m of any part of the Project system that is intentionally connected to the traction return system.
- 1.5.1.3 Earthing of the control and communications system should thus be by conventional methods to the protected earth of the distribution switchboard.
- 1.5.1.4 Additional protective measures should be adopted in the event that it becomes necessary to locate any item of equipment associated with the control and communication system within 2.5m of a part of the Project system that is connected to the traction return system during construction.

1.5.1.5 In such instances the provisions of sub-section A1.6 below, to limit the touch potential between the two earth systems should apply and the equipment enclosure should be earthed to the trunk earthing cable. The touch potential of this cable should be controlled as described within IEC 60634.

1.5.2 Station Equipment

1.5.2.1 Each item of control and communications equipment that is connected to an AC supply should have its earth terminal directly connected to the main protected earth terminal at the distribution board of that source by an appropriate protective conductor.

1.5.2.2 All metalwork (including enclosures, mountings etc.), associated with an item of control and communications equipment that is not intended to carry current should be bonded to the earth terminal within the equipment enclosure.

1.5.2.3 Alternatively, if the design of the equipment requires, a direct earth cable to the station earth farm principal earth connection, should be provided.

1.5.3 Trackside Equipment

1.5.3.1 Control and communication equipment at trackside locations, e.g. point machines, should derive their power supply from the nearest station or the depot as appropriate. Each item of control and communications equipment that is connected to an AC supply derived from this source should have its earth terminal directly connected to the main system earth cable running between the earth systems of successive service substations. In these cases the earth core of the supply cable should be left open at the end remote from the supply to avoid excessive currents during fault conditions.

1.5.3.2 All metalwork (including enclosures, mountings, etc.), associated with an item of control and communications equipment that is not intended to carry current, e.g. signal lamp enclosures, should be bonded to the main system earth cable running between the earth systems of successive service substations. The touch potential of the trunk earthing conductor should be controlled as described within IEC 60634.

1.5.4 Substation Equipment

1.5.4.1 Control and communication equipment, housed within or immediately adjacent to substations, should derive their power supply by dedicated AC feed from the station or depot as appropriate.

1.5.4.2 Each item of control and communications equipment that is connected to an AC supply derived from this source should have its earth terminal directly connected to the protective earth terminal at the distribution board of that source.

1.5.4.3 All metalwork (including enclosures, mountings etc.), associated with an item of control and communications equipment that is not intended to carry current should be bonded to the equipment earth terminal.

1.5.4.4 The earth terminal of the distribution board should be connected to the distribution switchboard protective earth.

1.5.5 Depot equipment

1.5.5.1 Depot equipment comprises all control and communications equipment contained within or mounted on the depot buildings and in the external areas.

Signalling and telecommunications room

1.5.5.2 Equipment contained within the signalling and communications should be fed from a distribution board, installed complete with protective devices and earth terminal.

1.5.5.3 Power distribution to the various items of ancillary equipment and cubicles should be by means of several ring main or radial circuits.

1.5.5.4 Each circuit should contain a dedicated protective conductor (separate conductor or cable armouring) connected to the protected earth terminal at the distribution switchboard. All items of control and communication equipment should have a direct connection between the equipment earth terminal and the circuit protective conductor.

Operations control centre

1.5.5.5 Equipment contained within the Control centre should be fed from a UPS distribution board, installed complete with protective devices and earth terminal.

1.5.5.6 Power distribution to the various items of ancillary equipment and desks should be by means of several ring main or radial circuits.

1.5.5.7 Each circuit should contain a dedicated protective conductor (separate conductor or cable armouring) connected to the protected earth terminal at the distribution switchboard. All items of control and communication equipment should have a direct connection between the equipment earth terminal and the circuit protective conductor.

Other depot locations

1.5.5.8 Control and communication equipment, located externally or on depot buildings, may derive its power from an AC source.

1.5.5.9 Internal earthing of the equipment should be to a dedicated earth terminal connected to the enclosure.

1.5.5.10 Where the equipment is outside the 2.5m limit to the vehicle static envelope an earthing circuit for the metallic enclosure should be provided back to the protected earth of the distribution switchboard.

1.5.5.11 Where the equipment is within the 2.5m limit, the enclosure should be earthed to the depot system earth. The touch potential of this earth system should be controlled by strategically situated voltage limiting devices.

A1.6 Earthing of other metallic structures

1.6.1 General

1.6.1.1 Other metallic structures comprise those structures that do not form part of the Power Supply or Communication and Control Systems covered in sub-sections A1.4 and A1.5

above. Examples include the reinforcing in concrete construction, pipes for other services and fixtures and fittings in buildings and stations.

- 1.6.1.2 Lightning protection of structures and buildings is also included in this section.
- 1.6.1.3 The fundamental point of difference between the principles of earthing applied to the AC and DC traction systems dictates the application of self-restoring spark gaps:
- a) The AC systems should be generally arranged to operate with their neutrals earthed, and with associated metallic enclosures also connected to earth, by conventional methods;
 - b) The DC main line traction return system should not be earthed deliberately at any point, and should be insulated to a level of at least $10\Omega/\text{km}$, in order to control stray earth currents and mitigate their effects on buried metalwork.
- 1.6.1.4 This principle creates two conflicts of design criteria such that the AC earthing system must not be permanently connected to the DC traction return system, as it would create a DC earth leakage path.
- 1.6.1.5 As the DC main line negative return system is not deliberately earthed, it can attain unacceptable step and touch voltages with respect to AC earthing systems, and the loop resistance introduced can render DC earth faults difficult to detect and interrupt. Hence VLD's; self-restoring spark gaps or 'floating negative automatic grounding switches' (FNAGS) at TSS's, should be used at various locations, for either or both of the following purposes:
- a) to hold the touch or step voltage to an acceptable level (normally during DC fault clearance); the devices should be fitted where deliberately-earthed metalwork is closer than 2.5m to the traction return rails, or vehicle Static Envelope ('Deliberately earthed' is defined as being connected to the earthing of a power system); and
 - b) to convert a DC 'earth' fault into a detectable 'positive-to-negative' fault; the devices should be fitted where earthed metalwork is vulnerable to contact from the 750V DC supply.
- 1.6.1.6 The self-restoring properties of high voltage limiting devices avoid a permanent leakage path for limited faults whereas a latched contactor needs to be manually reset or a Soule device needs to be physically replaced.
- 1.6.1.7 In view of the uncertainty about compliance with the 2.5m clearance in specific locations for which detailed design has yet to be completed, FNAGS should be fitted, in any case, at all traction substations between substation earth and negative busbars and between the trunk earth cable between service substations and the running rails.

Reinforced concrete track slab

- 1.6.1.8 Where reinforced track slab incorporates separate dedicated stray current collection mats of rebar construction (in the case of a DC traction system with traction return through the running rails), the steel work of such mats should be kept electrically separate from that of the rest of the reinforcement in the track slab.

- 1.6.1.9 Successive stray current collection mats may be linked to each other in succession by disconnectable links.
- 1.6.1.10 At each link position one side of the link may be connected to a trunk 'stray current collection/monitoring cable' of suitable section. The trunk collection cable may be duplicated for each track and each terminated at both ends on insulators adjacent to the station earthing system with the possibility of connecting to the earth system through diodes for stray current collection if later deemed beneficial. The diodes may be provided at the outset and installed together with the connection terminals such that they can be connected or not as may be required.
- 1.6.1.11 The stray current collection/monitoring cable should be insulated and protected from earthed metal along its route.
- 1.6.1.12 All track slab reinforcing in the workshop area, where the tracks are earthed, should be bonded to the earthed rebar and steel structures of the workshop building.

Services to project premises.

- 1.6.1.13 Metallic service (i.e. water, gas, waste water etc.) pipes entering the Project premises, both over and underground, should be provided with an insulated insert at the point of entry, and the pipework within the Project premises should be bonded to the local earth system.
- 1.6.1.14 Where both plastic and metal pipes are used, all lengths of exposed metal pipes, or those connected to taps or apparatus, should be bonded to the local earth system. A separate bond should not be required for the pipe if it is electrically continuous with earthed apparatus.
- 1.6.1.15 If a normal DEWA supply is brought onto the railway premises for non-railway usage, consideration should be given to the use of isolating transformers at the boundary.

1.6.2 Underground structures

Exposed structural steelwork

- 1.6.2.1 All exposed structural steelwork should be bonded to the nearest local earth system. The bonding should be by bare copper strip or other approved conductor, and/or the structural steelwork itself provided any joints should be electrically continuous or should be bridged by a bonding conductor.

Pipework

- 1.6.2.2 Pipework should be bonded to the local earth systems of the locations through which the pipework passes and all joints between individual lengths of pipe should be electrically continuous or bridged by a bonding conductor
- 1.6.2.3 Pipework should be bonded to all adjacent exposed structural steelwork and other metalwork such as walkways, cable and pipe supports etc. either directly or, where there is a local earth system, via the bonding to the local earth system of both pipework and the structural steelwork.

- 1.6.2.4 Alternatively, pipes should be broken down into limited conductor lengths between proprietary insulated joints. In this case, pipe hangers along the length of each section should be insulated from the pipe with insulation of nominal 2kV 'flash test' withstand. In this case, the centre of each run of pipe, so insulated, should be connected to an adjacent earthed structure by bare copper strip or other approved conductor.

Steelwork in tunnels

- 1.6.2.5 All steelwork in tunnels forming walkways and supports for pipes, cable trays and racks should be bonded and earthed to the nearest trunk earth cable in both directions by bare copper strip or other approved conductor.
- 1.6.2.6 Small isolated metallic components need not be earthed, e.g. individual metallic cable cleats, fixing bolts for plastic cable cleats.

1.6.3 Aboveground structures

Building frames and structural steelwork

- 1.6.3.1 This section covers the structural steel frames of depot and workshop buildings, and similar structural steelwork.
- 1.6.3.2 The frames of all buildings and other structural steelwork should be bonded to the local earth system unless all parts of the frame or structure are completely encased in concrete, masonry or other non-metallic cladding.
- 1.6.3.3 Where a local earth system is not provided under the provisions of sub-section 1.5.4 above, such a system should be provided for the purposes of this section in those locations where accidental contact with the traction system is possible. Such an earth system should have an overall resistance not exceeding 10Ω between any point of the earthed frame or structure and the general body of the earth. In addition a self-restoring spark gap device should be connected between each separate structure and the traction return system
- 1.6.3.4 Isolated metallic structural parts of a building, whether encased or not which are not in contact with any other metalwork are included under sub-section 1.5.4 above.
- 1.6.3.5 In the case of the building structure of the depot workshop, where the traction return system is deliberately earthed, the structure E&M service and traction earthing systems should all be interconnected.
- 1.6.3.6 In general the reinforcing bars in concrete structures or foundations should not be earthed in those cases where the reinforcing bars are completely encased in concrete. This applies to substation foundation slabs.
- 1.6.3.7 Where external connections are made to the reinforcing, for the purpose of providing studs for securing metallic structures or components which are earthed, insulating sleeves and washers should be fitted to the studs if there is a possibility of traction return currents passing into the reinforcing via the studs.
- 1.6.3.8 The reinforcing in concrete track slab should be connected in accordance with 'Reinforced concrete track slab' covered above.

Small metallic components

- 1.6.3.9 Small metallic and isolated structural parts which are effectively segregated from any electrical apparatus or cables and the like, or earthed metallic enclosures and structures do not require to be bonded to the local earth system.
- 1.6.3.10 For the purposes of this section, the metal angle supports for trench covers and similar metalwork in electrical traction and distribution substations are not effectively segregated and should be bonded to the substation earth system.

Depot fencing

- 1.6.3.11 Metallic fencing associated with the Project within 2.5m of the track or any part of any structure or other equipment which is connected to it, should be earthed to the depot slab structural earth system. The depot substations should also derive their earthing from the depot slab structural earth system. Consideration should be given to the use of non-conductive components where the fence cannot be located 2.5m from the track
- 1.6.3.12 Each separate section of fencing should be separately earthed in the appropriate manner as above.
- 1.6.3.13 All gate posts should be bonded to each other across the gate opening by an underground conductor, and the gates themselves bonded across the hinges.

OCS poles and structures

- 1.6.3.14 All metallic fittings and equipment not intentionally energised should be effectively grounded.
- 1.6.3.15 OCS poles and structures should be connected to impedance bonds where possible.
- 1.6.3.16 Surge arresters installed on the OCS should be connected to the earthing system independently via earth conductors, earth rods and/or earth farms.

1.6.4 Lightning protection

- 1.6.4.1 The need for lightning protection for individual buildings should be assessed in accordance with IEC 61024-1 or the local building code. Where lightning protection is found to be necessary, it should be provided in accordance with this standard.
- 1.6.4.2 All building structures should be of steel or steel reinforced concrete with every pillar of the structures bonded into the structure earth of the depot slab.
- 1.6.4.3 Metal roofing should be multiple bonded into the metal of the building structure.
- 1.6.4.4 Lightning conductors should be provided to bridge any non-metallic roofing and conduct into the steel structure in the most efficient manner.
- 1.6.4.5 Cables with metal sheaths and other metallic services entering the building should be bonded to the structure at the point of entry and to any electrodes provided for lightning protection, if not already adequately bonded via the local earth system.

1.6.5 Clearance between earthed structures and the track

1.6.5.1 As a general rule, no part of any earthed metallic structure should be closer than 2.5m from the main line rails, any metalwork bonded to the rails, or the Static Envelope of the vehicles themselves. More detailed consideration of this requirement, and of methods to be used where the requirement is violated, is given in IEC 60634.

1.6.5.2 The above rule does not apply in the depot workshop, where the track is deliberately earthed.

A1.7 Corrosion control

1.7.1 Measures to reduce corrosive traction return currents

1.7.1.1 Long term evidence shows that corrosive effects are not expected from AC traction systems, so corrosion control should only be applied to stray currents flowing from DC traction systems.

1.7.1.2 Since it is neither practicable nor desirable to completely insulate the track, it is not possible to prevent traction return DC currents entering buried structures which are located in the proximity of the track.

1.7.1.3 The following measures should be considered to reduce corrosion and other interference effects unless safety considerations dictate otherwise:

- a) ensuring that the along-track resistance is as low as practicable;
- b) ensuring that the track-to-earth resistance is as high as possible, consistent with safety considerations (a figure of at least $10\Omega/\text{km}$ should be maintained for tunnels and at least $2\Omega/\text{km}$ for open air);
- c) ensuring that the average stray current per unit length does not exceed $2.5\text{mA}/\text{m}$ (average stray current per length of a single track line). Or, as it is not always practicable to measure the stray current directly, ensure that the average value of potential shift between the structure and earth in the hour of highest traffic does not exceed $+200\text{mV}$ for steel in concrete structures;
- d) providing a substantial buried collector mat in slab track sections, with successive sections interconnected with insulated cables and possibly connected to an earth reference at the ends via diodes.

1.7.1.4 The Stray Current Corrosion Control (SCCC) system for steel wheel on steel rail systems with DC traction supply should be designed with the following objectives:

- a) provide a SCCC system that should ensure the required design life for railway structures;
- b) provide facilities to mitigate the stray current effects on the facilities and structures; and
- c) provide facilities to remotely monitor stray current levels from the OCC.

1.7.2 Design Considerations

1.7.2.1 The SCCC system should include as a minimum the following:

- a) isolation and/or control of all possible stray current leakage paths to minimise stray current effect on system and adjacent structures, public utilities;
- b) detection and monitoring of stray currents which do occur;
- c) stray current drainage (collection) system

1.7.2.2 The amount of stray current that may leak out from the track and power systems should be ascertained. Based on this amount of leakage current, a quantitative analysis of the corrosion effects on the structure should be prepared and appropriate provisions made in the design to ensure that the required design life is achieved.

1.7.3 Operating Modes

1.7.3.1 It is expected that the system should normally be running in open mode (drainage circuit not connected). When monitoring shows that stray currents are excessive and remedial measures are unsuccessful, drainage mode should be employed.

1.7.3.2 The drainage mode should be set in operation by the Railway Operator by closing the isolator in the drainage panel in the relevant traction substation. Drainage mode should also be selected for testing.

1.7.4 System Components

Cabling

1.7.4.1 For underground stations and tunnels, low smoke, halogen free, fire retardant type cables with armouring should be provided.

1.7.4.2 For above ground stations and viaducts, fire retardant type cables with armouring should be provided.

1.7.4.3 All cables should have an insulation level of 2000V DC and be single core, multi-stranded copper conductor and XLPE insulated.

Drainage Panels

1.7.4.4 A drainage panel should be provided in each traction sub-station. It is used to provide a connection path between the drainage terminal box and the negative return box. The drainage circuit can only be activated by manually closing the isolator. The circuit should be supplied with variable resistors to restrict the current flow and should be further protected by a fuse for overcurrent protection.

1.7.4.5 Drainage panels should consist of the following components:

- a) diodes;
- b) surge absorber;
- c) resistor unit;
- d) transducer;
- e) shunt;

- f) meter unit;
- g) fuse unit;
- h) termination assemblies;
- i) insect protection mesh;
- j) isolator; and
- k) two stage, changeover SCADA alarm contacts that are programmable.

Drainage Terminal Boxes

- 1.7.4.6 Each drainage terminal box should be provided with connection terminals for the monitoring cable and the drainage cable. Connections between terminals should be provided within the box by tinned copper busbars or approved equivalent.

Reference Electrodes

- 1.7.4.7 Reference electrodes should be installed in underground stations in the outside wall at each end of each station at convenient locations for connections to be made.
- 1.7.4.8 Each electrode terminal should be covered by a suitable terminal box for protection.

1.7.5 Stray Current Leakage Path Control

General

- 1.7.5.1 No stray current leakage paths should be formed between structural units or between the structure and piped services, handrails and other metallic components located along the guideway. Dielectric insulation should generally be provided to prevent stray current leakage.
- 1.7.5.2 No fixings or cabling for the trackwork should affect the track insulation system or reduce substantially the track to earth/structure resistance.
- 1.7.5.3 Stray current leakage should not give rise to any safety hazards to customers or operations staff.

Installations

- 1.7.5.4 Electrical insulation from the transit or Depot structure should be provided for installations located along the guideway where necessary. Examples may include:
- a) signalling equipment and/or their supports;
 - b) platform screen doors;
 - c) blue light station support frames and siding telephone support frames;
 - d) metal pipes;
 - e) lightning protection system to viaducts;
 - f) earthing cables;
 - g) sectionalising switches, high-speed circuit breakers and their supports; and

h) control boxes, test boxes, junction boxes etc. and/or their supports.

Underground Structures and Tunnels

- 1.7.5.5 The design should incorporate appropriate methods to prevent ponding of seepage water around track fastenings.
- 1.7.5.6 Handrails, walkways and other continuous metallic elements along the guideway should be electrically insulated from the structure.
- 1.7.5.7 Tunnel segments should be electrically separated from each other across all circumferential joints.
- 1.7.5.8 All non-railway metallic service pipes passing through or embedded within the structure should be insulated from the structure by a plastic sleeve.