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TECHNICAL REPORT

colour inside

Railway applications – Specification and demonstration of reliability, availability, maintainability and safety (RAMS) –
Part 3: Guide to the application of IEC 62278 for rolling stock RAM

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Part 3: Guide to the application of IEC 62278 for rolling stock RAM

FOREWORD

The main task of IEC technical committees is to prepare International Standards. However, a technical committee may propose the publication of a technical report when it has collected data of a different kind from that which is normally published as an International Standard, for example "state of the art".

IEC 62278-3, which is a technical report, has been prepared by IEC technical committee 9: Electrical equipment and systems for railways.

This technical report is based on EN 50126-3.

This technical report is to be read in conjunction with IEC 62278 (2002).

The text of this technical report is based on the following documents:

Enquiry draft	Report on voting
9/1284/DTR	9/1315A/RVC

Full information on the voting for the approval of this technical report can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

IEC 62278 is likely to enhance the general understanding of the issues involved in achieving RAMS characteristics within the railway field. It defines a comprehensive set of tasks for the different phases of a generic life cycle for a total rail system. Although some of the examples given in the annexes of IEC 62278 are for rolling stock, the standard is essentially aimed as a top level railway system document.

RAMS characteristics for rolling stock (i.e. its long-term operating behaviour performance), as for any other system, form an important part of its overall performance characteristics. But the consideration of RAMS, in contractual terms, between a customer / operator and a main supplier for the procurement of rolling stock has been problematic. Also, in rolling stock contracts, there is now a greater emphasis on the impact on end customers of service failures and on the economic and risk considerations of RAMS (i.e. the business perspective).

Consequently, Life Cycle Cost is being used as a measure of satisfying customer needs and providing a wider perspective of RAMS importance in terms of the business economics.

Life cycle cost approach represents a holistic, total cost of ownership philosophy for addressing economic considerations. The contribution of RAMS to the LCC (Life Cycle Cost) of rolling stock could be used to allow economic considerations to be addressed.

This application guide focuses mainly on the tasks and issues from procurement, engineering and maintenance, from the tender to the operation/maintenance phase, and is intended to help in establishing a common approach for capturing the different, time dependant, performance requirements of rolling stock from an operator/business perspective.

IEC 62278 is a standard, which treats the overall aspects of RAMS in railway applications.

This guide deals with the application of RAM part of IEC 62278 to rolling stock only, as stated in the scope and clarifies areas where IEC 62278 could be misinterpreted.

RAILWAY APPLICATIONS – SPECIFICATION AND DEMONSTRATION OF RELIABILITY, AVAILABILITY, MAINTAINABILITY AND SAFETY (RAMS) –

Part 3: Guide to the application of IEC 62278 for rolling stock RAM

1 Scope

This part of IEC 62278 provides guidance on applying the RAM requirements in IEC 62278 to rolling stock and for dealing with RAM activities during the system life cycle phases from invitation to tender to demonstration in operation only. All references to IEC 62278 concern the 2002 issue.

The guide is aimed at the customers/operators and main suppliers of rolling stock. The main purpose of the guide is to:

- enable a customer/operator of rolling stock:
  - to specify the RAM requirements addressing the type of operation in terms of the end customer needs, considering service availability and economic considerations;
  - to evaluate different tenders, in terms of RAM requirements, on a common basis with the aid of specific RAM documents;
  - to gain assurance, during design/development phase, that the rolling stock being offered is likely to satisfy the RAM contractual requirements by examining step by step detailed and specific RAM documents as an output of the RAM activities performed during the development phase;
  - to validate that the rolling stock, as delivered, satisfies the specified RAM requirements;
- to enable the main supplier of rolling stock;
  - to understand the customers/operators RAM requirements;
  - to provide substantive information/visibility in a tender to show that the product offered is likely to satisfy the RAM requirements by performing preliminary RAM analysis;
  - to provide substantive information during design/development phase to show that the product offered is likely to satisfy the RAM requirements by performing detailed RAM analysis;
  - to demonstrate that the product delivered satisfies the RAM requirements.

Regarding LCC, this application guide is restricted to providing only the key RAM parameters necessary to be incorporated into an LCC model.

This application guide excludes:

- RAM values connected to the different RAM requirements (however, it contains a simple guideline of actions for supporting the decision making process and choosing appropriate values, see 5.4);
- specific RAM documents to be produced and activities to be performed. However, it provides, only as an example, typical data and document templates for recording the output of a RAM analysis).

2 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 62278 and the following apply:

2.1
part number
the alphanumeric code, generally assigned by the main supplier, to represent a family of items with the same characteristics of form, fit and function

3 Approach adopted for the guide

3.1 General

The approach adopted is to raise the following questions, for each phase of the Life Cycle, in order to successively set up the requirements of IEC 62278 and the basis for satisfying them:

- WHAT: what activities / tasks are to be performed and the supporting documents to be produced?
- WHO: who has the responsibility for these activities / tasks?
- HOW: which type of method or tool should be used?

This process is adopted for the development of the guide and should be applied in accordance with the structure of the application guide.

3.2 Entities involved in the life cycle phases of rolling stock

Depending on the organisational and management structure of the railway system concerned, a number of entities, performing different functions, may be involved within the life cycle phases of rolling stock. For the purpose of guidance on contractual relations, the entities are divided into 2 main categories, i.e. customer and supplier.

It is therefore advisable, to identify all the entities that can be a part of this relationship and to examine how the responsibilities of dealing with these entities are shared between the customer and supplier relationship. Table 1 gives some typical examples only.

Table 1 – Possible sharing of responsibility

Entity	Supplier responsibility	Customer responsibility
Main supplier of the rolling stock	X	
Sub-supplier of the rolling stock	X	
Operator of the rolling stock		X
Owner of the rolling stock		X
Maintainer of the rolling stock	X	X

4 Application of this guide

4.1 Object of the application

This guide is applicable to rolling stock (train, coach, locomotive, etc.) and to all the subsystems, assemblies and parts belonging to the rolling stock, according to their boundary limits.

Referring to 1.2 of IEC 62278, the guide is for use by Railway Authorities and the railway support industry and is applicable to:

- new rolling stock,
- modification/refurbishment of existing rolling stock.

For use in this document only, the above two bullet point items should be referred to by the generic term “system”, comprising the complete sequence “system, sub-system, component” of a rolling stock or the whole rolling stock itself breakdown structure.

4.2 Application of IEC 62278

4.2.1 Assessment of the application of IEC 62278

Referring to 5.3 of IEC 62278 and taking into account the responsibilities of the different entities involved in the life cycle phases, the following subclause gives a synthesis of the main actions required to meet the requirements.

According to 5.3.2 of IEC 62278, the assessment of the application of the requirements of IEC 62278 to rolling stock (system under consideration) shall be defined by the Railway Authority and according to 5.3.4 of IEC 62278, the assessment shall:

a) Specify phases applicable, and for each one of these:
   - Justify and demonstrate the compliance with the principles of the requirements of the standard.
   - Specify the mandatory activities/requirements, with respect to rolling stock (system under consideration), including:
     1) The scope of each requirement,
     2) The methods, tools and techniques required against each requirement and the scope and depth of their application,
     3) The verification/validation activities required against each requirement and the scope of their application,
     4) Input/output documentation.
b) Justify any deviation from the activities and requirement of the standard.
c) Justify the adequacy of the tasks chosen for the system under consideration.

Both the customer and the main supplier should provide documented evidence for the above specifications and justifications that are within their responsibility.

Where main supplier introduces limitations, they should be discussed and agreed with the customer.

These documents are considered as part of the RAM programme.

4.2.2 Mandatory requirements for the application of IEC 62278

The correct application of IEC 62278 is effected through several requirements.

The following is a synthesis of the mandatory requirements in 5.3.5 of IEC 62278 regarding RAM only:

- define and agree the responsibilities for carrying out all RAM tasks within each phase chosen;
- ensure the competence of the personnel involved within RAM tasks;
- establish and implement a RAM programme, where the following should be identified and managed:

  – conflicts between RAM and safety tasks,
  – details of all RAM analysis, including the depth of analysis activities;
- ensure that the requirements of IEC 62278 are implemented within business processes, supported by a Quality Management System (QMS) compliant with the requirements of ISO 9000 series;
- establish and implement an adequate and effective configuration management system including, at least:
  – all system documentation,
  – all other system deliverables.

Both the customer and the main supplier should provide evidence by documents about the fulfilment of these mandatory requirements, within their responsibility.

These documents are considered as part of the RAM programme.

5 Specifying RAM requirements

5.1 Introductory remarks

The purpose of this clause is to establish the process to define RAM requirements for rolling stock and for all the subsystems, assemblies and parts belonging to the rolling stock according to its boundary limits.

This clause gives detailed information on phases 1, 2, 4 and 5 of system life cycle requirements described in 6.1, 6.2, 6.4 and 6.5 of IEC 62278.

To start with, as part of the system definition process, all available data and relevant information about the rolling stock under consideration should be collected.

The final goal is the derivation of RAM targets through the appropriate analysis of all the information collected and organised in a structured way.

5.2 Preliminary RAM analysis

5.2.1 General

This subclause complements 6.1.3.4, 6.2.3.1, 6.2.3.2, 6.4.3.1 and Clause A.2 of IEC 62278 and gives further details.

The purpose of the preliminary RAM analysis is to identify the application environment and the operating conditions of the rolling stock, in order to recognise the fundamental concepts for basing the overall RAM requirements.

The analysis involves undertaking the following activities:

- similar system review:
  – a list of similar existing rolling stock is created, suitable for extracting relevant RAM-related information;
- preliminary system analysis:
  – all available and relevant rolling stock documentation is reviewed in order to define, at a preliminary level, the overall system structure and its mission profile and to recognise the system failure conditions.

Deliverables of the preliminary RAM-related activities constitute the necessary background for defining the overall RAM requirements specification in terms of:

– RAM requirements.
– Demonstration and acceptance criteria.
– RAM programme requirements.

5.2.2 Preliminary RAM analysis activities

5.2.2.1 General

Preliminary RAM-related activities consist of investigating all the relevant available documentation in order to recognise all the functional requirements, which may affect the RAM performance of the rolling stock.

The resultant deliverables of the preliminary RAM-related activities are:

- System identification: where the rolling stock has to be identified in terms of its boundary limits, operational conditions, functions, interfaces, system breakdown structure, logistics and maintenance conditions.
- Failure conditions: where the failures of the rolling stock have to be identified and categorised in order to define appropriate requirements.

5.2.2.2 System identification

This subclause provides a general overview of the main features identifying a rolling stock (see IEC 62278, Clause A.2).

The identification process is carried out to gain assurance that the rolling stock is correctly analysed and all the factors influencing its RAM performance have been identified.

These characteristics define the conditions under which the rolling stock is required to accomplish its mission and constitute the reference conditions for:

- defining the rolling stock RAM requirements;
- demonstrating, by analysis and tests, that each specific implementation fulfils the RAM requirements in all relevant lifecycle phases.

The main characteristics and features necessary to describe a rolling stock are its mission profile, route profile, operating conditions, environmental conditions and maintenance conditions (including logistics). Items contained in each of these are listed below:

a) Mission profile:
    - Reference route,
    - Commercial speed (mission duration / mission length),
    - Mean length of a run,
    - Mean distance between train stops,
    - Operating time or distance per year,
    - Revenue operating time or distance per year,
    - Stand-by time per day,
    - Idle time per day (i.e. time when the rolling stock is neither in operation nor stand-by),
    - Planned total time of use (life expectancy in years).
b) Route profile:
    - Number of tunnels related to reference route,
    - Number of viaducts related to reference route,
    - Cumulative distance in tunnels,

- Cumulative distance on surface, including viaducts,
- Gradients and curves on the route with their lengths.

c) Operating conditions:

- Equivalent speed related to the time the equipment is powered during a given calendar period (cumulated distance / Time the equipment is powered over the period),
- Time an equipment is powered over a given calendar period (this parameter could be defined for each equipment, but is generally defined for categories of equipment),
- Time during which traction is activated,
- Time or percentage of time during which electric braking is activated,
- Operating time of the compressor,
- Number of compressor startups,
- Time of presence of catenary power, for each voltage,
- Time during which a trainset is awake (i.e. in operation or standby),
- Operating time for Heating Ventilation and Air Conditioning, in heating mode and in air conditioning mode,
- Average speed and maximum speed,
- Potential use in multiple units,
- Total time of coupled operation,
- Frequency of coupling and de-coupling,
- Internal temperature range of the rolling stock,
- Mechanical (shock and vibration),
- Electrical (power supplies),
- Electromagnetic compatibility (e.g. EMC – train to train or system to system),
- Signalling interfaces (e.g. on-board and way-side),
- Ergonomics.

d) Environmental conditions:

- Outside air temperatures (OAT),
- Maximum height above the sea level,
- Solar radiation,
- Humidity,
- Wind and pressure pulses,
- Water and precipitation,
- Pollutants and contaminants,
- Resistance to corrosion.

e) Maintenance conditions:

- Indicative maintenance plan (i.e. minimum preventive maintenance interval, maximum contemporary number of personnel required for maintenance interval tasks, maximum standstill time to complete maintenance interval tasks, etc.),
- Number, location and description of the sites for maintenance,
- Description of the standard equipment, tools and resources at the maintenance sites.

5.2.2.3 Breakdown structure and boundary limits

5.2.2.3.1 General

Breakdown structure of the rolling stock is the most important baseline of the identification process. Establishing a breakdown structure of the rolling stock, gives a clear reference outline for all the activities and analyses for supporting RAM programme through the life cycle.

Generally, the scope of the breakdown structure is to set up the borders of a system by listing all the items belonging to that system and, by using an appropriate number of discrete breakdown levels for the system, to draw out the relationships existing between the different items of the rolling stock.

There are two categories of structures to support RAM analyses:

- Functional breakdown structure,
- Physical breakdown structure.

The functional breakdown is used to perform preliminary criticality analyses. The last functional level allows consequences of functional failure modes to be developed and the next physical level allows the critical item list to be developed.

The physical breakdown is used to perform maintainability analyses. The last level of this breakdown is the LRU (Line Replaceable Unit), as defined in 5.5.4.4. This breakdown is sometimes called the logistic breakdown structure.

5.2.2.3.2 Common rules to set up a physical breakdown structure

For setting up a breakdown structure, a decomposition process is carried out starting from the first level to the other levels identified and being able to represent all the items and their functional relationships.

The decomposition process is based on a hierarchical breakdown in a top down process commencing with the rolling stock as the system under consideration.

At each level identified in the hierarchy, every system identified becomes the next system under consideration and can be further decomposed into lower levels, as necessary.

There are several methods and tools to set up a breakdown structure. The following are recommendations to be followed in order to develop an appropriate and suitable breakdown structure for RAM purposes:

- Avoid the use of "large number of levels" and limit these to a reasonable number (three or four are suggested),
- Last item identified along a branch shall be a LRU,
- Force the use of the same terms and definitions for identical items,
- Ensure that the terms and definitions used for every item are the same in all the design documents (drawings, outlines, diagrams, specifications, etc.),
- After the first issue of the structure avoid continuous modifications,
- Avoid the use of vague or unclear definitions.

The definition used for LRU is well explained in 5.5.4.4.

5.2.2.3.3 Data to identify the physical breakdown structure

Every breakdown structure shall be presented together with a set of drawings, diagrams, and functional outlines in order to meet the target of identifying the rolling stock and all its subsystems, assemblies and parts, clarifying at least:

- all the relationships between the items of the breakdown structure,
- the functional borders between different systems, subsystems, assemblies.

A minimum set of data is used to represent and to manage the breakdown structure.

This kind of data is the baseline of the different analyses that should be carried out during the life cycle.

Every breakdown structure should be represented with a header containing at least the following (see Table 2):

Table 2 – Example of minimum set of data of the header for a form representing a breakdown structure

Subject	Details
Rolling stock	ID code or definition of rolling stock
Doc. N.	Code of document
Version Number	Number to identify the version of the document
Date	Date of document referred to the version of the document
Page n/N	Consecutive number of page/total number of pages
Drawn up by	First and last name of author
Filename	Name of file of the document

The following (see Table 3) are the minimum set of data to represent a breakdown structure:

Table 3 – Example of minimum set of data representing a breakdown structure

Subject	Details
Code	Breakdown level code of the item
Description	Description of the item
Qty	Amount of the item under consideration in the higher level item
Part No.	Part No. of the item
NOTE 1 The use of quantity information is suggested for breakdown structure where the product is defined.	
NOTE 2 As appropriate, it is recommended to use the Part Number for every item of the breakdown structure.	

Examples of breakdown structure are given in Annex A.

5.2.2.4 Failure Conditions

This subclause complements 4.5.2.2 and 6.4.3.2 of IEC 62278 and gives further details.

The following general failure conditions are defined for the rolling stock based on general failure categories, which may be experienced by a generic railway transport:

- Immobilising failures,
- Service failures,

- Minor failures.

Table 4 shows the failure categories indicated in IEC 62278 and defines them in terms of their application to rolling stock.

Table 4 – RAM failure categories

Failure category	Definition
Significant (Immobilising failure)	A failure that: – prevents train movement or causes a delay to service greater than a specified time and/or – generates a cost greater than a specified level
Major (Service failure)	A failure that: – must be rectified for the rolling stock to achieve its specified performance and – does not cause a delay or cost greater than the minimum threshold specified for a significant failure
Minor	A failure that: – does not prevent rolling stock achieving its specified performance and – does not meet criteria for significant or major failures

In order to better define the above mentioned failure categories the following conditions are applicable to rolling stock and to all its subsystems, assemblies and parts:

- Significant failure (immobilising failure): Any failure occurring on rolling stock and leading, at least, to one of the following conditions:
  - A delay greater than a specified time,
  - Train stopped on the track,
  - Train not allowed to enter service,
  - Withdrawal of the train from service,
  - A cost greater than a specified threshold.
- Major failure (service failure): Any failure occurring on the rolling stock and leading, at least, to one of the following conditions:
  - A delay less than a specified time,
  - Loss of specific functions or their performance threshold falling below the specified minimum acceptable level,
  - A cost less than a specified threshold.
- Minor failure:
  - Any failure occurring on the rolling stock, that is not classified as significant or major, leading to a maintenance task, even if this failure has no impact on service.

According to the above mentioned definitions and conditions of failures, the customer should state:

- The number of minutes of delay for significant failures and major failures,
- The threshold cost for significant failures and major failures,
- The method for counting the delay (i.e. at the end of the run only, cumulated during all the stops, the maximum between two stops, etc.),
- Specific service conditions which are deemed to result in stopping the train on the track or withdrawing the train from service in case of significant failure,

- Functions and their performance thresholds, which are deemed to be classed as Major Failures (e.g. the failure of the passenger air-conditioning, the failure of driver's cab air-conditioning, the failure of door system per side, the failure of a specified number of toilet system, the failure of the coach lighting system, etc.).

Tables 5 to 7 show the specifications for each failure category.

Table 5 – Significant failure specification

Failure category	Conditions	Threshold dimension	Specification requested
SIGNIFICANT (immobilising failure) $Fail_I$	Delay greater than or	Time	Specify mode of counting delay
	Train stopped on the track or		Rolling stock unable to proceed under its own power.
	Withdrawal of the train from service/Train not allowed to enter service or		Specify special service conditions under which the customer decides that the train is withdrawn from service or stopped from entering service
	Cost greater than	Money	Specify reference cost

Table 6 – Major failure specification

Failure category	Conditions	Threshold dimension	Specification requested
MAJOR (service failure) $Fail_S$	Delay less than or	Time	Specify mode of counting delay
	Failing specified performance or		Specify services/functions and their performance threshold levels below which the customer considers it as service failure
	Cost less than	Money	Specify reference cost

Table 7 – Minor failure specification

Failure category	Conditions	Threshold dimension	Specification requested
MINOR $Fail_M$	Any failure occurring on the rolling stock	Time	

It should be noted that one or more conditions for each table of failure category might be applied.

5.3 RAM requirements

5.3.1 General

This subclause complements 4.5.2.2 and 6.4.3.2 of IEC 62278 and gives further additional details.

The aim of this subclause is to give an overview of the most commonly used RAM requirements in order to help the customer choose the most appropriate requirements for his rolling stock, and also take into account any possible legal requirements, when existing.

In choosing the appropriate RAM requirements, the customer is strongly advised to consider the following:

- System identification characteristics (mission profile, operating condition, function requested, etc.),
- Economic implications,
- Practicalities of being able to measure RAM performance from his field operations, depending on his organisational and logistical structure and service procedures.

The customer should document his process for choosing RAM requirements stating the consideration given to address each requirement chosen.

5.3.2 Reliability targets

This subclause provides guidance on description of reliability targets required for the failure categories significant (Immobilising), major (Service) and minor failure. (i.e. MTBF in hours, failure rate per million hours, or failure rate per million km).

The reliability targets are applicable to the total rolling stock and all its subsystems, assemblies and parts according to the boundary limits defined.

Using the above definition the customer should specify the reliability targets for each one of the failure categories in terms of:

- Maximum accepted failure rate,
- Minimum accepted MTBF/MTTF/MDBF.

The terms hours/kilometres represent hours/kilometres of service.

MTBF requirement is intended for repairable units and MTTF is intended for non-repairable units.

If the real service operating time for the rolling stock and for its subsystems, assemblies and parts could not be measured, the customer can choose, as appropriate, the following:

- Maximum accepted failure rate,
- Minimum accepted MDBF.

In addition, the customer could specify reliability targets for important systems/subsystems. In such a case the customer could apply the following definition for failures affecting important systems/subsystems:

- Any failure occurring on a defined system/subsystem and leading to failure in meeting a specified performance,
- Any failure occurring on a defined system/subsystem and leading to a maintenance task, even if this failure has no impact on service.

The customer should specify the failure conditions in which the defined system/subsystem does not accomplish its specified performances.

Table 8 groups the above reliability requirements:

Table 8 – Reliability requirements for failure categories

Applicable to	Requirement	Dimension	Symbol
Rolling stock	Max accepted failure rate	Number / Million km Or Number / Million hours	$FR_{I/S/M}$
	MTBF/MTTF/MDBF	hours or km	$MTBF_{I/S/M}/MTTF_{I/S/M}/MDBF_{I/S/M}$
System/ subsystem 1	Max accepted failure rate	Number / Million km Or Number / Million hours	$FR_{I/S/M}$
	MTBF/MTTF/MDBF	hours or km	$MTBF_{I/S/M}/MTTF_{I/S/M}/MDBF_{I/S/M}$
System/ subsystem 2	Max accepted failure rate	Number / Million km Or Number / Million hours	$FR_{I/S/M}$
	MTBF/MTTF/MDBF	hours or km	$MTBF_{I/S/M}/MTTF_{I/S/M}/MDBF_{I/S/M}$
System/ subsystem …	Max accepted failure rate	Number / Million km Or Number / Million hours	$FR_{I/S/M}$
	MTBF/MTTF/MDBF	hours or km	$MTBF_{I/S/M}/MTTF_{I/S/M}/MDBF_{I/S/M}$
System/ subsystem n	Max accepted failure rate	Number / Million km Or Number / Million hours	$FR_{I/S/M}$
	MTBF/MTTF/MDBF	hours or km	$MTBF_{I/S/M}/MTTF_{I/S/M}/MDBF_{I/S/M}$

The customer can establish different tables for each failure category specifying the requirements applicable for each table and adding an index I, S or M for indicating the different failure categories (Immobilising, Service, Minor).

The requirements applicable to systems/subsystems of the rolling stock have to be referred to the breakdown structure in which each system/subsystem is clearly identified (for breakdown structure see 5.2.2.3).

It should be noted that converting MTBF into MDBF, a predefined average speed is necessary, where the average speed is based on specific requirements of the mission profile (see 5.2.2.2).

5.3.3 Maintainability targets

This subclause provides guidance on description of the maintainability targets required for rolling stock and for all its subsystems, assemblies and parts according to the boundary limits defined.

For a rolling stock and for its subsystems, assemblies and parts according to the boundary limits defined, there are different types of maintainability targets:

- Generic qualitative requirements (e.g. accessibility, disconnecting, removing, handling, installing, reconnecting, standardisation, etc.),

- Preventive maintenance requirements (qualitative/quantitative) (e.g. frequency, maximum number of personnel related to each frequency, maximum number of hours related to each frequency, etc.),
- Corrective maintenance requirements (qualitative/quantitative) (e.g. MTTR, Maximum TTR, etc.),
- Logistic support requirements (e.g. supply and administrative delay, spare parts availability, etc.),
- Maintenance cost requirements.

5.3.3.1 Generic qualitative requirements for maintainability

The qualitative requirements for maintainability should consider at least the following (see Table 9), as an example:

Table 9 – Qualitative requirements for maintainability

Accessibility	The equipment layout, including their relevant connections, should be arranged in such a way as to make it possible to easily perform inspections, repairs, revisions, replacement, etc., taking into consideration the dimensions of the tools that may be necessary to perform these operations, the working area necessary for the maintenance personnel, the safety standards and possible need for localised illumination. All fastening points of the equipment and interfacing points between it and its infrastructures (e.g. ventilation channels, fans, filters, etc.) should, as a rule, be accessible without the need for special tools.
Dismounting	It must be possible to remove any piece of equipment if needed for recovery from failure or for scheduled maintenance, without having to operate on other pieces of equipment not directly involved with the specific maintenance action. Evaluation of removability of an item should also take into account the possible need for removing parts of the rolling stock structure (e.g. hatches, casings, etc.) and the ease of removing or opening and handling them.
Modularity	In designing equipment every opportunity should be applied to increase the modularity of the object so as to reduce intervention time, the specialisation of the personnel required and the stocks to be kept on hand. Modularity should make it possible to divide maintenance activities into two levels: primary maintenance (rapid replacement of the unit), secondary maintenance (repair the unit off the train, e.g. in the workshop).
Handling	Every piece of equipment, device and item of furnishing subject to dismantling for replacement, repair or programmed maintenance should not exceed the weight supportable by a single person and should be capable of being manually handled by a single person. This maximum weight may be doubled when the conditions of accessibility make it possible for two persons to work together. The external features of the shape of the unit in question should make it easy to handle and not hazardous or capable of injuring the personnel. In the case of objects that have to be removed using mechanical hoisting equipment and/or transportation, the layout and construction should provide for making available the necessary provisions for hooking, fastening, hoisting with a forklift (eyebolts, hooks, feet, etc.). If the hooking, hoisting or transportation equipment is not available on the market, it shall be designed, constructed and supplied under the responsibility of the main supplier. The connections existing between the unit and the structure and between the unit and other interconnected units should be accessible, able to be disconnected and reconnected and not subject to corrosion or rust in relation to the environment in which they are located.
Ease of cleaning	All environments, apparatus, flooring and coverings should be designed in such a way as to facilitate all operations of cleaning to the utmost. In particular as regards passenger vehicles and environments, textile coverings that can be cleaned efficiently should be used. Carpeting and wall-to-wall textile flooring should be designed for easy replacement for cleaning off the rolling stock by providing appropriate breaks especially in the environments subject to heavy traffic (corridors, vestibules, etc.). The main supplier should indicate the cleaners compatible with the materials and coverings used. As a general rule, in the visible environments, all efforts should be made to avoid sharp corners, indentations, complicated relief patterns or hollows where dirt could accumulate or that could be difficult to clean. This should be verified on the mock-up.
Standardisation	Solutions used should, to the maximum extent, make it possible to interchange parts with others already in use by the customer and installed on other rolling stock. In particular, for elementary objects, commercial or unified solutions should be used, or parts already in use by the customer as classified replacement parts. For parts already in use by the customer, he should supply a list. For parts unique to the customer, he may reserve the right, if necessary, for such parts to be restricted for his sole use. There should also be a close match between the drawings and the effective realisation of the pneumatic and electric circuits for all rolling stock of the same supply.
Interchangeability	It should be possible to remove an item and install another one in its place without affecting any equipment characteristics. The replacement should be compatible in form, fit and function.
Testability	Objects should be designed in such a way as to make it possible to identify their condition clearly and rapidly. This means that it should be possible to perform, as far as practicable, preventive diagnostics so as to check the condition of the object before a failure occurs and to be able to perform corrective diagnostics in order to identify clearly which item may be malfunctioning or damaged.

5.3.3.2 Preventive/corrective maintenance requirements

Preventive/corrective maintenance requirements can be of two types:

- general (referred to all the maintenance actions),
- specific (referred to maintenance actions on a sub-system).

Examples of general and specific requirements are as follows (see Table 10):

Table 10 – Preventive/corrective maintenance requirements

Definition	Dimension	Proposed symbol
Minimum interval for scheduled maintenance	time, kilometres	$MinInt_{sm}$
Maximum standstill time to complete maintenance actions	time	$MaxST_{cm}$
Maximum allowed number of personnel employed for maintenance	dimensionless	$MaxANP_{m}$
Maximum man-hours for a specific maintenance action	time	MaxMMH
Maximum allowed time for dismounting/mounting	time	$MaxAT_{d-m}$
Maximum allowed time for detecting/isolating/replacing faulty items	time	$MaxAT_{d-i-r}$
Fault coverage	dimensionless	FC
Mean time to restore (corrective maintenance)	time	MTTR
Mean time to maintain (preventive maintenance)	time	MTTPM
Mean time to maintain (corrective maintenance)	time	MTTCM
Mean time between maintenance (preventive maintenance)	Time, distance, cycles	MTBPM
Mean time between maintenance (corrective maintenance)	Time, distance, cycles	$MTBCM_{c}$

5.3.3.3 Logistic support requirements

Typical logistic support requirements could be (see Table 11):

Table 11 – Logistic support requirements

Definition	Dimension	Proposed symbol
Maximum allowed time to reach maintenance site	time	$MaxAT_{rm}$
Maximum allowed time to plan maintenance actions (time for taking spare parts from storage depot, time for taking tools and diagnosis equipment)	time	$MaxAT_{pm}$
Probability of spare parts on stock when needed	dimensionless	SOR
Turn around time (for repairable spares)	time	TAT
Lead time (for non repairable spares)	time	LT
NOTE If it is not possible to measure time to reach maintenance site or to plan maintenance actions, contractual fixed times can be used.		

5.3.3.4 Maintenance cost requirements

The maintenance cost constraints can be expressed in different ways.

One way to consider maintenance cost is to require maximum allowed values within an agreed period of time.

In this case the customer should specify which items are counted as maintenance cost and the agreed period of time for counting.

Examples of items for maintenance cost are as follows (see Table 12):

Table 12 – Maintenance cost requirements

Definition	Dimension	Proposed Symbol
Training of maintenance personnel	Money	T_{mp}
Travel costs sustained for reaching the maintenance sites	Money	T_{cm}
Spare parts acquisition, provision and storage	Money	$SP_{a\text{-}p\text{-}s}$
Preventive (scheduled) maintenance actions (including cost for spare parts, for software and for personnel employed)	Money	PM_c
Corrective maintenance actions (including cost for spare parts, for software and for personnel employed)	Money	CM_c

Other maintenance cost requirements can be the cost of preventive or corrective maintenance (or the sum of the two) where the customer can use the cost per kilometre or per 1 000 km or other significant basis (i.e. per year, per vehicle-train, per seat).

Also in this case customer should specify what this cost includes, detailing the items counted.

As appropriate, the customer may specify targets for important sub-systems of the rolling stock (e.g., bogie, supply power module, doors, air conditioning system, toilet, etc.).

5.3.4 Availability targets

This subclause provides guidance on description of the availability targets required for rolling stock and for all its subsystems, assemblies and parts according to the boundary limits defined.

Based on Annexes A and C of IEC 62278, availability A of a rolling stock is specified as the time for which a rolling stock is in a state to perform its mission.

Availability formula is generally indicated by the following:

$$A = \frac{MUT}{MUT + MDT}; \quad \text{with } 0 \le A \le 1$$

where,

MUT is the mean up time;

MDT is the mean down time.

Availability over a predefined time interval T can then be calculated by stating the following items:

MUT (in hours)

MDT (in hours)

The resulting down time d (T) within a time interval T (e.g., 1 year) is:

$$d(T) = (1 - A) \times T$$

The availability number is dimensionless and is usually indicated as a percentage.

Depending on the definitions of MUT and MDT, it is possible to have different types of availability using the same formula:

- Inherent availability, Ai
- Achieved (technical) availability, Aa
- Operational (logistic) availability, Ao

For **Inherent availability**, **A**$_i$, the definitions used for MUT and MDT are:

MUT=MTBF=Mean Time Between Failures (hours).

MDT=MTTR=Mean Time To Restore (hours).

Then, the formula is:

$$A_i = \frac{MTBF}{MTBF + MTTR}$$

For **Achieved (technical) availability**, **A**$_a$, the definitions for MUT and MDT are:

MUT=MTBM=Mean Time Between Maintenance (hours).

MDT=MTTM$_a$=Mean Time To Maintain (hours).

In this case, MTTM$_a$ takes into account the mean time required to maintain rolling stock both for preventive and corrective maintenance.

Then, the formula is:

$$A_a = \frac{MTBM}{MTBM + MTTM_a}$$

For **Operational (logistic) availability**, **A**$_o$, the definitions for MUT and MDT are:

MUT=MTBM=Mean Time Between Maintenance (preventive and corrective) (hours).

MDT=MTTM$_o$=Mean Time To Maintain (hours).

In this case, MTTM$_o$ takes into account the mean time required to maintain rolling stock both for preventive and corrective maintenance, including logistical and administrative delays.

Then, the formula is:

$$A_o = \frac{MTBM}{MTBM + MTTM_o}$$

Another measure for availability that could be considered is the ratio of the number of rolling stock available for service in the monitored period and the whole fleet.

This is defined as **Fleet Availability**, FA, and the number of rolling stock available for service is determined by the difference between the number of rolling stock in the whole fleet and the number of rolling stock not available for service due to maintenance actions (preventive and corrective maintenance).

In this case, the formula is:

$$FA = \frac{F_{op}}{F_{tot}} = \frac{F_{tot} - F_m}{F_{tot}}$$

where:

F_{op}= number of rolling stock available for service

F_m= number of rolling stock not available for service due to corrective and preventive maintenance

F_{tot}= total number of rolling stock in the fleet.

Yet another type of availability is the **Schedule Adherence** (respect of the schedule), SA, measured as ratio of the number of journeys running according to schedule and the total number of scheduled journeys.

The number of journeys running to schedule can be determined by the difference between the total number of scheduled journeys and the number of journeys not running to schedule due to rolling stock related causes.

In this case the formula is:

$$SA = \frac{F_s}{F_{tot\_s}} = \frac{F_{tot\_s} - F_{ns}}{F_{tot\_s}}$$

where:

F_s= number of journeys running to schedule

F_{ns}= number of journeys not running to schedule due to causes concerning rolling stock

F_{tot_s}= total number of scheduled journeys

Table 13 groups the above mentioned availability requirements:

Table 13 – Availability requirements

Formula	**Definition**	**Dimension**
$A_i = \frac{MTBF}{MTBF + MTTR}$	Inherent availability	Dimensionless
$A_a = \frac{MTBM}{MTBM + MTTM_a}$	Achieved (technical) availability	Dimensionless
$A_o = \frac{MTBM}{MTBM + MTTM_o}$	Operational (logistic) availability	Dimensionless
$FA = \frac{F_{op}}{F_{tot}} = \frac{F_{tot} - F_m}{F_{tot}}$	Fleet availability	Dimensionless
$SA = \frac{F_s}{F_{tot\_s}} = \frac{F_{tot\_s} - F_{ns}}{F_{tot\_s}}$	Schedule adherence	Dimensionless

The customer should choose the availability requirements and should:

- Detail the factors of the formula chosen,
- Specify and take into account the responsibility for each factor,
- State the time interval of the monitored period,
- Consider system identification characteristics (mission profile, operating condition, function requested, etc.),
- Consider economic implications,
- Consider the practical possibility of measuring RAM requirements from his field operation depending on his organisational and logistical structure and service procedures.

NOTE Examples of logistical and administrative delays are as follows:

- Wait in the depot,
- Wait for spare parts,
- Time to prepare maintenance actions,
- Time necessary to shunt rolling stock.

5.4 Process for choosing RAM figures

This subclause complements 4.5.2.2 and 6.4.3.2 of IEC 62278 and gives further details.

The aim of this subclause is to provide simple guide line to help customers choose appropriate figures for RAM requirements.

Considering the deliverables of the previous subclauses of the guide the customer should:

- Analyse rolling stock system identification and its breakdown structure,
- Consider functional requirements involved and the related sub-systems,
- Derive RAM requirements by analysing the functional requirements for their failure conditions,
- Consider RAM requirements of similar rolling stock,
- Review past RAM performances achieved,
- Consider technical evolution of the rolling stock under consideration,
- Evaluate the impact of new functionalities requested,
- Consider a realistic improvement of RAM requirements,
- Consider other specific and documented needs.

The above actions would enable the customer to make better choices with substantial supporting documentation.

The customer should document his process for choosing RAM figures stating the consideration given to address each figure chosen.

5.5 RAM programme

5.5.1 General

This subclause complements 6.1.3.5, 6.2.3.2, 6.2.3.3, 6.4.3.3 and 6.5.3.2 of IEC 62278 and gives further details.

RAM programme is a set of activities to be performed along the system life cycle for ensuring that the RAM requirements stated for the rolling stock are fulfilled at each development phase.

An efficient RAM programme should be established and maintained over the whole life cycle by both, main supplier and customer, taking into account the whole range, including variations, of operational possibilities to be chosen during the life time of the rolling stock.

Within RAM programme, each entity involved should define and plan activities, for each phase, that are within their responsibility.

RAM programme tasks should be managed in conjunction with the management of the general functional and technical tasks, over the life cycle, through periodic reviews. The review should ensure that the RAM requirements are being effectively addressed by providing substantive information / visibility of the tasks through appropriate RAM analysis.

RAM programme should be consistent with 4.2 of this technical report.

5.5.2 Configuration management system

A suitable configuration management system should be established and maintained by the main supplier. This should identify and document modifications to specific characteristics of a functional or physical item of the rolling stock. It should record and report the processing and implementation status of the modifications and the verification of their compliance with stated RAM requirements.

The main supplier is responsible for providing visibility of the configuration management process through documented activities and periodic reviews.

During the periodic reviews the main supplier should provide reports specifying, as a minimum, the following:

- Documents delivered, indicating the relevant revisions;
- Status and documentation, with objective evidence, of the current activities:
  - already carried out,
  - in progress,
  - to be carried out;
- Notification of problems affecting RAM requirements;
- Proposal for actions to resolve problems.

Since configuration control applies to all project phases (see IEC 62278 Figure 9, Note 1), when the project progresses through Phase 10 to Phases 11 and beyond, a suitable configuration management system should also be established by the customer.

5.5.3 RAM programme outline

An example of typical outline of RAM programme is shown below along with a list of contents:

1. INTRODUCTION:
1.1. PURPOSE
1.2. SCOPE
1.3. REFERENCE DOCUMENTS
1.4. DEFINITIONS AND ACRONYMS
2. DESCRIPTION OF THE SYSTEM
2.1. GENERAL DESCRIPTION:
2.2. SYSTEM BREAKDOWN:
3. RAM CONTRACTUAL REQUIREMENTS:
3.1. QUALITATIVE REQUIREMENTS
- Reliability requirements
- Maintainability requirements
- Availability requirements

3.2. QUANTITATIVE REQUIREMENTS
- Reliability requirements
- Maintainability requirements
- Availability requirements

4. RAM MANAGEMENT:
4.1. IMPLEMENTATION OF RAM
4.2. MANAGEMENT OF THE INTERACTIONS BETWEEN RAM ANALYSES AND QUALITY PLAN
4.3. CONFIGURATION MANAGEMENT PROCESS
4.4. ORGANISATION AND RESPONSIBILITIES
4.5. RAM MAIN ACTIVITIES:
- System Life Cycle Phases
- RAM activities during life cycle
- RAM documentation

5. RAM PROGRAMME PLAN:
5.1 ASSUMPTIONS AND SCOPE OF ANALYSES
5.2 METHODS AND TOOLS USED
5.3 RAM DETAILED ACTIVITIES, ANALYSES AND DOCUMENTS
- Periodical RAM Programme reviews
- System Condition and Mission Profile
- Reliability Modelling, prediction and apportionment
- FMECA analysis and Reliability Block Diagram
- Fault Tree Analysis
- Software Reliability analysis
- Corrective Maintenance Analysis
- Preventive Maintenance Analysis
- Fault isolation and trouble shooting actions Plan
- Reliability development/growth testing programme
- Maintainability preliminary tests
- Reliability demonstration tests
- Maintainability demonstration tests
- Failure data collection from field

5.4 FOLLOW UP OF RAM CRITICAL ITEMS
6. RAM DELIVERABLE DOCUMENTS AND SCHEDULE
6.1 LIST OF RAM DELIVERABLES
6.2 SCHEDULE FOR RAM ANALYSES
6.3 PERIODICAL RAM ACTIVITIES REPORT

The RAM programme plan establishes all the programme management tasks, in terms of timing and implementation details of the programme activities and documentation to accomplish the RAM programme requirements.

The RAM programme plan includes declarations for the procedures, tools and time schedule foreseen for implementing the RAM programme.

It should be noted that the main supplier is responsible for establishing the content of the RAM programme, for the RAM programme plan and for submitting these documents to the Customer for acceptance within the timescale agreed by the parties, in accordance with System Quality Plan.

5.5.4 Example of RAM analyses document template and data

5.5.4.1 General

The aim of this subclause is to provide an overview of RAM analyses document templates and data in order to give the user of the guide the ability to handle, with more practice, all the issues related to the RAM programme.

The following are examples of templates for the most common RAM documentation and analyses to be provided by the main supplier in order to give substantive information/visibility of the RAM activities carried out and to show that the rolling stock is likely to satisfy the RAM requirements in each phase of the life cycle from the tender to the operation phase.

A list of tools suitable for use to perform the different analyses and to manage all RAM activities is given in Clause B.5 of IEC 62278.

5.5.4.2 Common data for the analyses

This refers to a set of data for the identification of the object being analysed. These types of data are common through the different analyses and levels of the breakdown structure.

They represent the header of the analysis.

In order to simplify the common understanding, a three level breakdown structure has been considered in these examples and the third level is the LRU level.

Generally, as a minimum, the kinds of data are as follows (see Table 14):

Table 14 – Example of minimum set of data of the header for RAM analyses template

Rolling stock	ID code of rolling stock
L1 Code	Breakdown code of the level 1 assembly
L1 assembly	Description of the Level 1 assembly
L2 Code	Breakdown code of the higher assembly/subassembly
L2 assembly	Description of the Level 2 assembly
Drwg. or Diag. ref.	Identification number of drawing or diagram containing the identification references of the LRUs under consideration (code and description).
Doc.N.	Document code
Version Number	Number to identify the version of the document
Date	Date of document referred to the version of the document
Page n/N	Consecutive number of page/total number of pages
Drawn up by	First and last name of author
Filename	File name of the document

5.5.4.3 Reliability prediction analysis template and data sheets

Reliability prediction sheets should contain the following information (see Table 15 and Figure 1):

Table 15 – Example of minimum set of data for reliability prediction sheets

Code	Breakdown code of LRU
Description	Description of LRU
Part No.	Part No. of LRU
Failure rate (in failures/ Mh)	Failure rate of LRU expressed in number of failures per million hours
MTBF (h)	MTBF of LRU in hours
Qty	Amount of LRU in L2 assembly
Total failure rate (in failures/Mh)	Total failure rate, obtained as the product between the failure rate of the LRU and the qty of the LRUs in the L2 assembly
Total MTBF (h)	Total MTBF referred to the total failure rate
Total failures rate (in failures/Mkm)	Total failures per million km of the LRU
Total Qty	Total no. of LRUs in the whole rolling stock
Source of failure rate	Origin of the failure rate indicated (also codes of data sources used)
Notes	Any possible clarifications on the origin of the failure rate and correction factors introduced

It should be noted that where failure rate is expressed in Failures/Mkm, MDBF (Mean Distance Between Failures) is used.

As in the following example (see Figure 1), the header also contains data for L2 assembly (total failure rate and MTBF).

Reliability Prediction Sheets

Rolling Stock	Code L2	Doc. N.
Code L1	L2 Assy	Version Number
L1 Assy	Drwg or Diagr Ref	Date of version
		Drawn up by
		Page n/N
		File name

L2 Assy total Data

Code LRU	LRU Description	Part Number	Failure Rate (f/10^6 h)	MTBF (h)	Qty	Total F. Rate (f/10^6 h)	Total MTBF (h)	Total Failure Rate (f/Mkm)	Total MKBF (km)	Total Qty	Failure Rate Source	Notes

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Figure 1 – Example of reliability prediction analysis sheet

5.5.4.4 Maintenance attributes (maintenance levels, skill level and LRU definition)

Within railway field there are several definitions and attributes of maintenance.

The purpose of this subclause is to address every practical maintenance action in order to clarify the issues affecting RAM requirements and also to give an example of a maintenance organisation/modelling.

This example may be different to the organisation of the parties involved.

Generally, most railway operators would have an existing depot for the rolling stock with trained personnel, resources, and a minimum set of spare parts, tools and equipment to carry out maintenance. The target for the depot is to minimise standstill time for the rolling stock in order to release it, ready for service, following completion of maintenance within the lowest possible time.

Where the complexity of maintenance actions, related to the trained personnel, resources, minimum set of spare parts, tools and equipment available within the depot, does not meet this target, the maintenance actions need to be carried out elsewhere, e.g. within a specialised depot/workshop, and the rolling stock would be out of service for the duration.

The first situation is commonly referred to as "In-Service Maintenance" and the second one as "Out-of-Service Maintenance".

Considering the above situations and as the main purpose of the analyses is to meet RAM requirements, there are 2 possibilities for carrying out **preventive maintenance**:

a) In-service maintenance: In this case two choices can be considered for addressing the target of minimising standstill time:
   - All the scheduled maintenance actions are carried out in the depot,
   - Only removing/installing of items (replacing an item with a spare) is carried out in the depot. Other maintenance actions are carried out on the removed items in a specialised depot/workshop.
b) Out-of-service maintenance: In this case only one choice can be considered:
   - All the scheduled maintenance actions are carried out in a specialised depot/workshop.

For these situations, the preventive maintenance analysis templates and data sheets can be used with the following two codes as "Maintenance Level Codes":

- InS-PM (In-Service Preventive Maintenance),
- OutS-PM (Out-of-Service Preventive Maintenance).

A similar situation occurs when **corrective maintenance** is considered, but in this case besides the resources of the depot (personnel, tools, equipment, and so on), also the failure mode shall also be taken into account as an attribute affecting the RAM requirements and then considering "repairable failure mode" and "not repairable failure mode the following cases are possible:

a) In-service maintenance: In this case two choices may be considered for addressing the target of minimising standstill time:
   - Repairable failure mode: All maintenance actions for the repair are carried out in the depot,
   - Not repairable failure mode: Only removing/installing items is carried out in the depot (replacing a failed item with a spare).
b) Out-of-service maintenance: In this case only one choice can be considered:

- Repairable failure mode: Both the removing/installing of items (replacing a failed item with a spare), and the other maintenance actions for the repair of the failed item are carried out in the depot/workshop

For these situations, the corrective maintenance analysis template and data sheets can be used with the following three codes as "Maintenance Level Codes":

- InS-CM - Rep (In-service corrective maintenance with repairable failure mode),
- InS-CM - Not Rep (In-service corrective maintenance with not repairable failure mode),
- OutS-CM (Out-of-service corrective maintenance).

Here below are listed the previously shown situations:

	Preventive maintenance		**Corrective maintenance**	
			Repairable failure mode	**Not repairable failure mode**
In-service (depot)	All the scheduled maintenance actions	Only removing/installing of items	All the maintenance actions to repair	Only replacing failed item with spare items
Out-of-service (workshop)	All the scheduled maintenance actions		All the maintenance actions to repair	

Several definitions of maintenance levels are known and usually "In-Service" maintenance is quite similar to "Light maintenance" or "first level maintenance" and also "Out-of-Service" maintenance is quite similar to "Heavy maintenance" or "second level maintenance".

Depending on the definition of in-service maintenance, the LRU (Line Replaceable Unit) may also be defined as follows:

LRU is the item on which in-service maintenance (both preventive or corrective) actions are carried out.

This definition could be used where the depth of the Breakdown Structure has been defined (see 5.2.2.3).

As an aid to establish "Skill Level Codes", the following are suggested as examples:

- Low skill level (Code "L"): Personnel with basic knowledge of the systems/subsystems and able to perform simple and easy tasks such as:
  – tasks where the item is directly visible (easily accessible without complex disassembling actions) and the task can be performed using standard tools (screwdriver, wrench, etc.);
- Intermediate skill level (Code "I"): Personnel with specific knowledge of the systems/subsystems and able to perform more advanced tasks such as:
  – searching for the item needing maintenance, using non standard tools/equipment (multimeter, gauge, tester, etc.) and performing disassembling tasks with the aid of diagrams and maintenance manuals;
- High skill level (Code "H"): Personnel with complete and specialised knowledge of the systems/subsystems and able to carry out complex tasks such as:
  – searching for the item needing maintenance, using sophisticated tools for technical measures (oscilloscope, logic state analyser, etc.) and performing fine tuning and disassembling tasks with the aid of drawings, diagrams and maintenance manuals.

5.5.4.5 Preventive maintenance analysis template and data sheets

Preventive maintenance analysis sheets should contain the following information (see Table 16 and Figure 2):

Table 16 – Example of minimum set of data for preventive maintenance sheets

Code	Breakdown code of LRU
Description	Description of LRU
Part No.	Part No. of LRU
Qty	Amount of LRU in L2 assembly
Step No.	Consecutive number used to identify each maintenance task
Maintenance task	Description of the preventive maintenance task
Spare parts and special tools	Description of the special equipment (not provided by the depot or workshop and in any case not easily available on the market) and materials necessary (consumables and spares)
Frequency	Frequency of the maintenance task (time or km)
Maintenance level	Codes of the maintenance levels used by the maintainer
Personnel	Number of persons necessary at the same time for the maintenance task described
Skill level	Code of the Skill level requested for the personnel to carry out the maintenance task
Spare parts cost	Unit cost of materials expressed in monetary unit
Man hours	Time required for the maintenance task multiplied by the number of persons necessary
Standstill time	Standstill time for the rolling stock during the maintenance task
Total qty	Total no. of LRUs in the whole rolling stock
Notes	Any notes, comments or remarks on the logistics or other (e.g. references to the maintenance manual)

The customer should define the man-hour cost to enable the cost calculation to be carried out in the sheets if the costumer requires labour costs.

As in the following example (see Figure 2), the header also contains data for L2 Assembly (Total cost for spare parts and man-hour).

Preventive Maintenance Sheets

		Doc. N.
Rolling Stock	Code L2	Version Number
Code L1	L2 Assy	Date of version
L1 Assy	Drwg or Diagr Ref	Drawn up by
		Page n/N
		File name

L2 Assy total Data

Spare Parts Cost (€/1000km)	Man-hour Cost (€/1000km)	Total Cost (€/1000km)

Code LRU	LRU Description	Part Number	Qty	Step N°	Maintenance Task	Spare Parts and Special Tools	Frequency	Maintenance Level	Personnel N.	Skill Level	Spare Parts Cost	Man-hour	Standstill Time	Total Qty	Notes

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Figure 2 – Example of preventive maintenance analysis sheet

As an aid to establish the maintenance plan the following sheet "Preventive maintenance sheet for a single frequency" contains rearranged data already contained within "Preventive maintenance analysis sheet" (Figure 3) and further data needed for logistic organisation.

This sheet only contains preventive maintenance data for an LRU maintained during the same frequency interval.

The frequency (time or km) under analysis has to be indicated in the header.

It also contains indications for future logistic organisation of the maintainer within the "Frequency total data", where the main supplier should indicate the following data for the frequency interval analysed:

- spare parts cost needed to complete all the maintenance tasks of the frequency interval,
- man-hour requested to complete all the maintenance tasks of the frequency interval,
- standstill time for the rolling stock to complete all the maintenance tasks of the frequency interval,
- maximum number of persons simultaneously involved to complete all the maintenance tasks of the frequency.

Preventive Maintenance Sheets for Frequency

Rolling Stock
Code L1
L1 Assy
Frequency

Code L2
L2 Assy
Drwg or Diagr Ref

Doc. N.
Version Number
Date of version
Drawn up by
Page n/N

File name

Frequency total Data

Spare Parts Cost (€)	Man-hour (h)	Standstill Time (h)	Max number of persons contemporary involved

Code LRU	LRU Description	Part Number	Qty	Step N°	Maintenance Task	Spare Parts and Special Tools	Maintenance Level	Personnel N.	Skill Level	Spare Parts Cost	Man-hour	Stand-still Time	Total Qty	Notes

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Figure 3 – Example of preventive maintenance sheet for a single frequency

5.5.4.6 Corrective maintenance analysis template and data sheets

The corrective maintenance analysis sheets should contain the following information (see Table 17):

Table 17 – Example of minimum set of data for corrective maintenance sheets

Code	Breakdown code of LRU
Description	Description of LRU
Part No.	Part No. of LRU
Qty	Amount of LRU in L2 assembly
Failure mode	Failure Mode analysed for the LRU referring the FMECA analysis sheet
Maintenance task	Description of the corrective maintenance task
Spare parts and special tools	Description of the special equipment (not provided by the depot or workshop and in any case not easily available on the market) and materials necessary (consumables and spares)
Failure rate (in failures/Mh)	Failure rate of the failure mode of the LRU expressed in number of failures per million hours
Maintenance level	Codes of the maintenance levels used by the maintainer
Personnel	Number of persons necessary at the same time for the maintenance task described
Skill level	Code of the skill level requested for the personnel to carry out the maintenance task
Spare parts cost	Unit cost of materials expressed in monetary unit
Man hours	Time required for the maintenance task multiplied by the number of persons necessary
Standstill time	Standstill time for the rolling stock during the maintenance task
Total quantity	Total no. of LRUs in the whole rolling stock
Notes	Any notes, comments or remarks on the logistics or other (e.g. references to the maintenance manual)

The customer should define the man-hour cost to enable the calculation of costs to be carried out in the sheets if the costumer requires labour costs.

As in the following example (see Figure 4), the header also contains data for L2 Assembly (Total cost for spare parts and man-hour).

Corrective Maintenance Sheets

		Doc. N.
Rolling Stock	Code L2	Version Number
Code L1	L2 Assy	Date of version
L1 Assy	Drwg or Diagr Ref	Drawn up by
		Page n/N
		File name

L2 Assy total Data

Spare Parts Cost (€/1000km)	Man-hour Cost (€/1000km)	Total Cost (€/1000km)

Code LRU	LRU Description	Part Number	Qty	Failure Mode	Maintenance Task	Spare Parts and Special Tools	Failure Rate (f/10^6 h)	Maintenance Level	Personnel N.	Skill Level	Spare Parts Cost	Man-hour	Standstill Time	Total Qty	Notes

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Figure 4 – Example of corrective maintenance analysis sheet

5.5.4.7 Failure mode effects and criticality analysis template and data sheets

FMECA can be carried out to examine functions or items; the following example (see Table 18) shows an items analysis. The items FMECA sheets should contain the following information as shown in Figure 5:

Table 18 – Example of minimum set of data for items FMECA sheets

Code	Breakdown code of LRU
Description	Description of LRU
Part No.	Part No. of LRU
Quantity	Amount of LRU in L2 assembly
Function	Short description of the function performed by the LRU
Failure mode	The predicted or observed results of a failure cause on the LRU in relation to the operating conditions at the time of the failure
Failure cause	The circumstances which have led to a failure
Failure rate (in failures/Mh)	Failure rate of the failure mode of the LRU expressed in number of failures per million hours
Local effects	Worst effects of the failure mode on the LRU
Effect on next higher assy.	Worst effects of the failure mode on the L1/L2 assembly
Effects on rolling stock	Worst effects of the failure mode on the rolling stock, also considering its possible effects on other assemblies or subassemblies
Criticality	Code of the category of criticality of the failure mode according to a stated table of reference considered on the basis of its effects, affecting safety and/or service
Failure category description	Codes and description of the failure category according to the failure categories established
Diagnosis	Description of the method of detecting and identifying the failure mode, including diagnostics used to detect and identify
Preventive/corrective actions	Description of the measures or compensatory means suggested to prevent the failure mode or minimise its criticality or reduce/eliminate its effects.
Notes	Any notes, comments or remarks useful for the analysis

Note that the preventive/corrective actions must be addressed by:

- the designer when the FMECA is carried out during the design phase in order to improve the design of the rolling stock,
- the “on board” and maintenance personnel and then included in the maintenance and user manuals in order to improve the service of the rolling stock.

Regarding FMECA to examine functions, it is sufficient to consider the main functions by changing the header (deleting the structure reference) and by changing some columns (deleting the first four columns and inserting suitable columns for numbering functions, description of the main function, description of sub-function and description of phases of sub-function) in the example of the items FMECA sheet in Figure 5.

An example of a FMECA sheet to examine functions is shown in Figure 6.

It should be noted that “Function reference” in the example of FMECA sheet to examine functions represents the identification number of the functional block diagram where the function under consideration is detailed and the "N°" column represents the function reference number of the function under consideration within the functional block diagram (N° is only used where a functional block diagram contains more than one function).

Items FMECA Sheets

		Doc. N.
Rolling Stock	Code L2	Version Number
Code L1	L2 Assy	Date of version
L1 Assy	Drwg or Diagr Ref	Drawn up by
		Page n/N
		File name

Code	LRU Description	Part Number	Qty	Function	Failure Mode	Failure Cause	Failure Rate	Effects			Criticality	Failure Category	Diagnosis	Corrective Actions	Notes
LRU							(F/Mh)	Local	Assy	Rolling Stock					

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Figure 5 – Example of items FMECA sheet

FUNCTIONS FMECA Sheet

Rolling Stock	
Function Reference	

Doc.N.	
Version Number	
Date	
Page n/N	
Drawn up by	
Filename	

N°	Function	Sub function	Phase	Failure mode	Failure cause	Effects on			Criticality	Failure Category	Diagnosis	Preventive/Corrective Actions	Notes
						Local	Rolling Stock	Operation					

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Figure 6 – Example of functions FMECA sheet

6 RAM assurance during life cycle

6.1 RAM programme and phases of the life cycle

6.1.1 General

This subclause provides information supporting overall and preliminary RAM requirements.

It also gives information about activities and documentation during the life cycle phases supporting detailed specifications and requirements for the rolling stock including its systems and sub-systems.

Also, this subclause aims to define which phases of the system life cycle the RAM Programme deals with and provides more information about:

- activities to be managed,
- analysis and tools to be implemented,
- documentation to be provided

during the RAM Programme process.

Based on the above considerations, the RAM programme could be defined as shown in Figure 7.

Figure 7 – RAM programme and life cycle phases

All the entities involved in the rolling stock life cycle phases should also be established.

The following example (Figure 8) shows the integration process and the programme implementation when:

- The customer is also the operator and the maintainer,
- The main supplier is responsible for choosing his own sub-contractors/sub-suppliers.

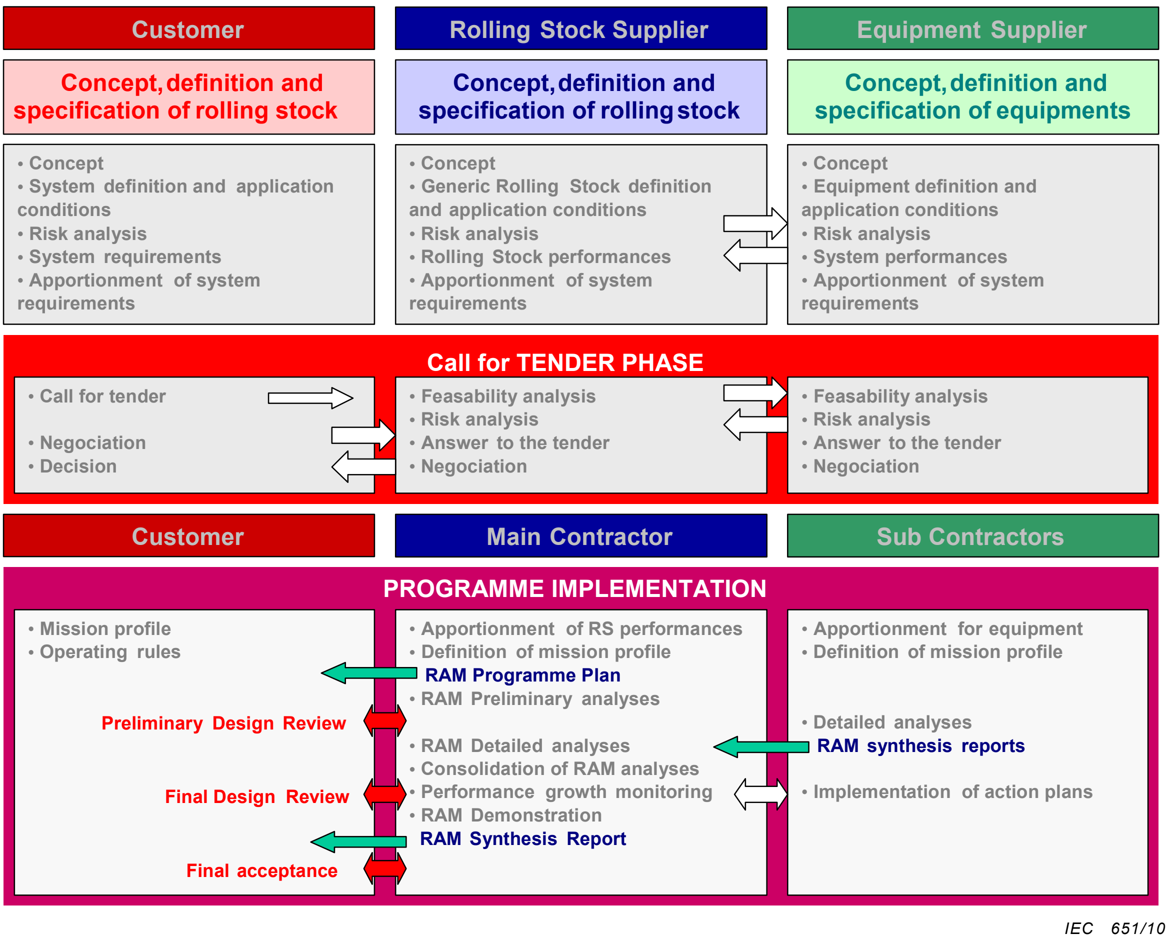

Figure 8 – Possible relationships between customer, main supplier, sub-supplier during some phases of life cycle for rolling stock

As stated within each phase of IEC 62278, deliverables of each phase form inputs to subsequent phases.

This consideration implies that the results of each phase shall be confirmed during successive phases.

6.1.2 Tender phase

The customer prepares tender phase (see Figure 7, life cycle phases 1 to 5) and the resultant call for tender document sent to the potential main suppliers.

Call for tender contains data about concept, definition and specification of rolling stock and RAM requirement to be fulfilled, according to Clause 5 of this technical report.

The customer should ask the potential main suppliers for RAM data and analysis during tender phase. This documentation is useful to enable the customer to compare the different offers on the same basis.

Examples of documentation to be requested during tender phase can be taken from design phase documentation (see 5.5.4).

Before responding to the call for tender, the main supplier has to perform relevant tasks, given below, to ensure that all risks related to the compliance with each requirement have been taken into consideration:

- Feasibility analysis: Enables determination of the best reasonable performances that can be achieved based on current experiences and past data, taking into account any differences in the new mission profile and/or the new system definition. This task is performed at rolling stock level, using current experience on similar applications and using analysis models like fault tree analysis or reliability block diagrams,
- Commercial risk analysis: Referring to the resulting best reasonable performances achievable from feasibility analysis, this task enables calculation of the probability of incurring penalties taking into account the gap between required and achievable performances,
- Response to the tender: Produce the RAM documents requested by the customer and write the RAM relevant sections of the offer and,
- Negotiation: Respond to queries/questions raised by the customer and/or support the negotiation team during the negotiation phase.

After receiving offers the customer evaluates the documents and chooses the best offer.

Usually a short phase of negotiation between the customer and the potential main supplier is planned, where contractual agreements are confirmed.

A contract award or a notice to proceed concludes the tender phase.

6.1.3 Design phase

This subclause gives details and practical information on phase 6 of system life cycle requirements described in 6.6 of IEC 62278.

The following flow chart (Figure 9) shows an example of the different RAM programme tasks to be implemented after contract award or notice to proceed.

The input documentation of this phase is the tender documentation presented by the main supplier and the contractual agreements confirmed during negotiation.

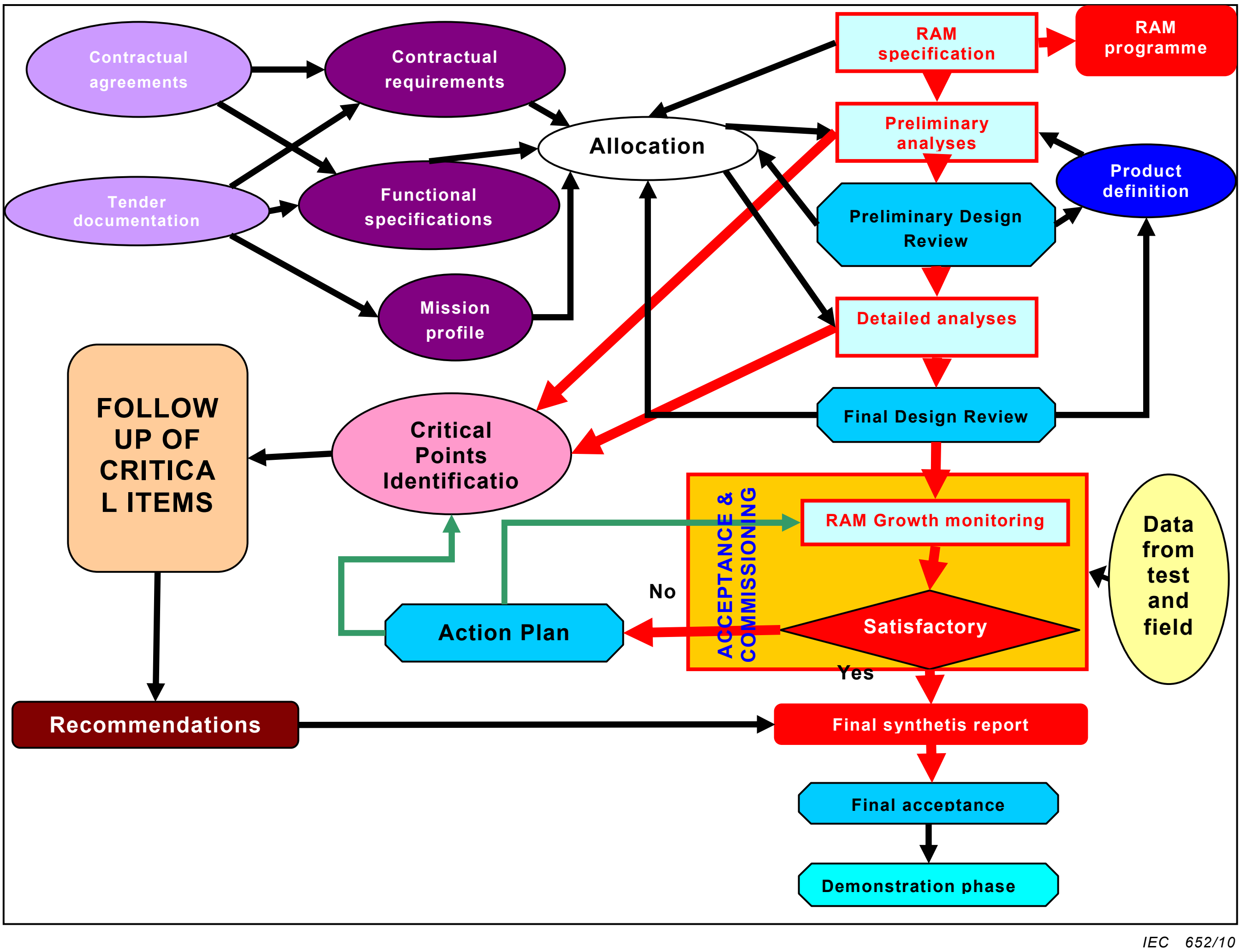

Figure 9 – Flow diagram representing activities/documentations of design phase

Table 19 gives a description of the tasks:

Table 19 – Description of the main tasks of design phase

Designation	Description of the task
RAM specification	After contract award, the first step is for the rolling stock main supplier to specify to the sub contractors, partners or equipment suppliers the contractual requirements related to the subsystems, functions or equipment in their scope of supply. Generally, it also includes the RAM programme delivery requirements for approval.
Preliminary analyses	The inputs of this task are the tender documents and the contractual agreements. Implemented at functional level, this task aims to highlight the critical RAM functions on which further detailed analyses should focus. During this phase, functions should be classified using the failure categories defined by the main supplier and adapted for the specific requirements of the contract. This task is performed using functional FMECAs to identify critical RAM functions and using reliability block diagrams. The deliverable of this task is a set of preliminary analysis to cover all the RAM requirements. Generally, the depth of analyses is limited to the level of breakdown structure for which, data and specification of the technical and functional design is available in sufficient detail.
Preliminary design review	This design process milestone is to check that design has progressed to preliminary stage. The RAM documentation should be reviewed at this milestone to ensure that RAM activities are in step with design progress, RAM requirements are being properly achieved and to examine any problems arising.
Detailed analyses	This task aims to perform detailed analyses highlighted during the preliminary analyses. During this task the main supplier should have progressed the design to sufficient detail corresponding to the LRU level of the rolling stock breakdown structure. Consequently, the analyses from the previous phase should be updated and detailed considerations given to the RAM. The final scope of such analyses is to ensure that the rolling stock design satisfies all the RAM requirements and the following: ❑ resolve any problems identified during previous analysis or review, ❑ verify the completeness of the set of documents, ❑ prepare activities for tests and for collection of field data. During this phase the main supplier should also collect detailed analyses carried out by sub contractors in order to: • Ensure a good consistency between them, • Integrate, in the analysis model, the predictions provided by them at equipment level, in order to get the predictions at rolling stock level, • Integrate interface mismatches in the model for the predictions.

Table 19 *(continued)*

Designation	Description of the task
Final design review	This design process milestone is to check that design has progressed to completion. RAM documentation should be reviewed at this milestone to ensure that all the RAM requirements have been properly achieved and to examine any problems arising. The final scope of this review is to: ❑ check the fulfilment of RAM requirements, ❑ resolve any outstanding problems ❑ verify the completeness of the set of documents, ❑ prepare activities for tests and collection of field data.
RAM growth monitoring	This task aims to monitor RAM growth (essentially reliability growth) so that the time to get steady state level is the shortest possible in revenue service. This task consists in the implementation of a problem solving process involving all the subcontractors and the main supplier in order to: ❑ Identify the problems occurring during the earliest operation phase, ❑ Highlight the top most problem contributors affecting contractual service performances, ❑ Implement an action plan to eradicate the problems or to mitigate their effects, ❑ Follow up the impact of such action plan to decide whether to carry on the iterative process or to stop it.
Follow up of critical items	This task is a specific management task implemented all along the design process from preliminary analysis to service operation. It consists of: ❑ Identifying, as part of the RAM analysis process (preliminary and detailed analysis), critical scenarios (i.e., failures effecting service or safety), ❑ Classifying these scenarios in a hierarchy based on the combination of their estimated frequency of occurrence and their effects on the level of safety or service, ❑ Proposing or asking the designers to propose actions or provisions to eliminate the scenarios or to mitigate their effects, ❑ Estimating the impact of the action plan, ❑ Following up application of these actions during the latest design phases or during manufacturing, This task is performed using problem solving techniques.

Note that the provisional calculation of RAM parameters described in this subclause is usually based on the use of probabilistic figures.

6.1.4 Demonstration phase

6.1.4.1 General

This subclause gives details and practical information on phases 9, 10, 11 of system life cycle requirements described in 6.9, 6.10 and 6.11 of IEC 62278.

This subclause deals with the operation period in which the customer should check the fulfilment of RAM contractual targets for the rolling stock under consideration by conducting RAM demonstration tests and collection of field data.

Collection of field data provides the customer with:

- A basis for rolling stock acceptance,
- A knowledge of the rolling stock performance,
- A reference data base for new rolling stocks/systems/subsystems tendering.

Also, collection of data from field enables the main supplier to:

- Monitor/verify design, manufacture and installation,
- Monitor rolling stock operation to address corrective actions,
- Gather data and knowledge for further and/or future development.

Also, for long term operation, the objective is to find out weak points in the management process (operation and maintenance phases) in order to form a basis for further performance improvement and cost reduction and to optimise maintenance and/or operation.

The definition of test procedures has to be consistent with the system identification process and definition given in Clause 5.

All the RAM documents provided during the design phase, according to the RAM programme, are intended to be proof of compliance with RAM requirements for the rolling stock.

6.1.4.2 RAM acceptance criteria

On the basis of the RAM requirements chosen, the customer should define the RAM acceptance criteria for the field.

The definition of reliability acceptance criteria should also specify the conditions under which a failure is classified as "chargeable", i.e. under main supplier responsibility, or alternatively is classified as "not-chargeable".

At least, the following general conditions of failure are to be considered as "not-chargeable" when verified:

- Failures occurred when operating outside the stated service conditions,
- Failures due to customer personnel,
- Failures due to accidental events.

Note that accidental events are intended to be events in which the system performances are degraded due to external causes which are not coming from the system itself, its normal operation, or the supplier staff.

In the same way the customer should define, before the beginning of the checking period and for each RAM requirement, detailed acceptance criteria in order to establish clear rules to be followed.

6.1.4.3 In service checking period

The customer is responsible for defining an appropriate duration for the checking period.

For defining a checking period, the customer should consider that usually RAM targets may not be achieved in the first period of operation but after a burn-in period, during which a reliability growth monitoring process should have been implemented.

Generally, the steady state level is achieved at least after two years of revenue service.

Reliability growth monitoring process is a continuous monitoring of the field data, successive RAM analysis and matching of the results against the targets for contractual requirements. Additional requirements may be agreed between customer and supplier.

Where results from field data fall short of contractual requirements, the main supplier should undertake corrective actions .

When choosing the checking period, it is important to highlight that:

- Within the reliability growth process, the corrective actions shall be managed as described in 5.5, with a corrective action plan, as appropriate.
- Before start of the RAM checking period, reliability growth process should be concluded.
- In order to manage a coherent field data collection, the rolling stock configuration status should have been stable and frozen. If technical modifications are necessary, the supplier should precisely quantify the consequences of modified configuration (e.g. software update).
- In choosing the duration of the checking period, the following should be taken into account:
  – number of rolling stock in the fleet and the cumulative annual kilometres of service,
  – maintenance plan of the rolling stock,
  – RAM requirements chosen by the customer,
  – duration of the contractual relationship between the customer and the main supplier (i.e. duration of warranty period).

The customer should also consider, as appropriate, whether the checking period and field data collection should cover

- the entire rolling stock fleet,
- a selected number of rolling stock of the fleet,
- other systems/subsystems of interest.

6.1.4.4 Data report from field and its organisation

Field data collection, within the checking period, comprises of gathering data on failures and the whole processing of the fault, such as:

- Failures during operation and maintenance,
- Classification of the failures (significant, major, minor),
- Structure code of the item source of the failure,
- Description of the fault detected,
- Work during maintenance,
- Amount of man-hours,
- Material consumption,
- Kilometres/hours of service,
- Downtimes and standstill times (also logistic and administrative delays).

Also, reports about repair and cause of failure are necessary to address the correct corrective actions.

Identification data has should be collected to enable traceability for further investigations, such as:

- Identification number of the report containing data,

- Date of the event occurred,
- Description of the operation status,
- Identification number of the rolling stock (or vehicle) within the fleet.

Also, preliminary information on probable cause, including technical evaluation, could be included to enable allocation of acceptance criteria.

Usually, the customer and the main supplier agree for a RAM demonstration plan to contain specification for, at least, the following:

- Rules and methods,
- Resource and tools,
- Organisation and responsibility,
- Field data collection sites (depots, workshops),
- Reference documents (i.e. RAM analyses and breakdown structure),
- RAM contractual targets,
- Acceptance criteria,
- Procedure for collecting data,
- Detection of all data source and any disturbances,
- Schedule of periodical field data collection reviews,
- Procedure to resolve problems and to address corrective actions,
- Procedure for implementing corrective action plan.

It is important to note that the corrective action plan should also contain the assessment of the impact of the corrective actions on the configuration management process as explained in 5.5.2.

7 RAM parameters to be incorporated into LCC model

7.1 General

The aim of this subclause is to give an overview of life cycle cost, pointing out the RAM parameters to be incorporated into a LCC model for rolling stock.

Life cycle costing is the process of economic analysis to assess the total cost of acquisition and ownership of a product. This analysis provides important inputs in the decision making process with regard to product design, development and use.

Railway customers and operators require railway products that are reliable, safe and can be easily maintained over their useful lives.

Using LCC, main suppliers can optimize their designs by evaluating alternative designs and/or configurations and by performing trade-off studies. In this way, they can evaluate various and different operating and maintenance strategies to optimize LCC.

Also, the LCC technique can be used to give a value to compare different offers and alternatives and to control the project.

As RAM requirements influence cost of rolling stock, they are the basis of any life cycle cost calculation.

7.2 Overview of LCC modelling

Life cycle cost is the cumulative cost generated by the rolling stock during its lifetime in respect to a LCC model. LCC modelling is a simplified representation of the main features of the rolling stock translating them into cost figures.

The basic elements of every LCC model may be the following:

- The physical structure of the rolling stock and its mission profile,
- The relevant phases of the lifetime to be considered,
- The relevant cost categories to be considered.

Regarding the first bullet item, consideration should be given to 5.2.2.3, breakdown structure and boundary limits, and its subclauses 5.2.2.3.1, 5.2.2.3.2 and 5.2.2.3.3, and to 5.2.2.2, system identification.

The second bullet item is well explained within IEC 62278 and, depending on the phases chosen, it also addresses the third bullet item.

In any case the total costs incurring during the main phases can be grouped under the following three categories:

- Acquisition costs,
- Ownership costs,
- Disposal costs.

Following this simple outline, the derivation of detailed sub-categories and costs can be easily carried out and so it makes modelling of LCC possible.

The completion of a suitable model is outside the scope of this guide but the above information is useful to give an overview and to better introduce the RAM parameters for inclusion into an LCC model.

For more detailed consideration for developing an LCC Model see IEC 60300-3-3.

7.3 RAM parameters for LCC

Starting from reliability parameters, Table 5 and Table 6 already contain, under column "conditions", parameters that can have direct impact on LCC.

Also, failure rate (or MTBF/MTTF/MDBF, see Table 8) has an impact on LCC. But this impact can be evaluated considering maintenance cost.

Maintenance cost is one of the most significant costs of the whole LCC.

Maintenance cost is time-variable when considering either corrective or preventive maintenance.

Corrective maintenance is larger for older rolling stocks than new ones, once the early failure period of new rolling stock has been overcome.

The proportion spent on preventive maintenance peaks in years when expensive actions are carried out (i.e., major inspections, replacement of expensive parts, refurbishing and overhaul, etc.). As these actions are only carried out two to five times throughout the service life, consideration should be given to these when preventive maintenance costs are evaluated. This should be considered to ensure that maintenance costs from different operators or from different rolling stock main supplier are compared on the same equal basis.

Regarding corrective and preventive maintenance costs, Figures 2 to 4 contain elements useful to build costs of items.

Parameters to be considered are:

- Spare parts costs (new or reconditioned),
- Working time per maintenance activity (man hour),
- Man hour cost,
- Maintenance interval (for each action in preventive maintenance) within maintenance plan during its lifetime,
- Quantities within the rolling stock breakdown structure,
- Reliability of the item maintained (failure rate, MTBF/MTTM/MDBF).

Derivation of the parameters related to availability is quite difficult, because they depend on the consequences caused by the lack of use of the rolling stock in service.

The immediate cost consequences due to unavailability of the rolling stock can be the following:

- Costs due to loss of revenue,
- Costs for providing an alternative service,
- Costs due to loss of image, reputation, prestige that may result in loss of clients.

Estimation of these costs is typically a commercial or marketing matter and then the derivation of costs related to unavailability could not have any relationship with the elements contained in 5.3.4. But when the estimate is to be based on the time (expressed in hour or days) during which the rolling stock is in a "down state" or alternatively when it is to be based on the journeys not operated, the parameters of Table 13 can be easily applied.

Annex A
(informative)

Examples of breakdown structure

A.1 General

This annex is intended to give a generalised illustration to the text describing the RAMS processes. It is not intended to conflict with nor should it be confused with EN 15380 which is a designation system for railway vehicles.

A.2 Introductory remarks

Two possible ways of representing a structure are highlighted below:

- The organisation chart (see Figure A.1),
- The tree breakdown chart (see Figures A.2 and A.3).

The following gives an example of the organisation chart for a rolling stock "EMU (Electrical Multiple Unit) COACH", where for visual purposes only two branches have been developed.

	TREE BREAKDOWN STRUCTURE		
ROLLING STOCK: EMU COACH		Doc. N.	
		Version Number	
		Date of version	
		Drawn up by	
		Page n/N	
		File name	

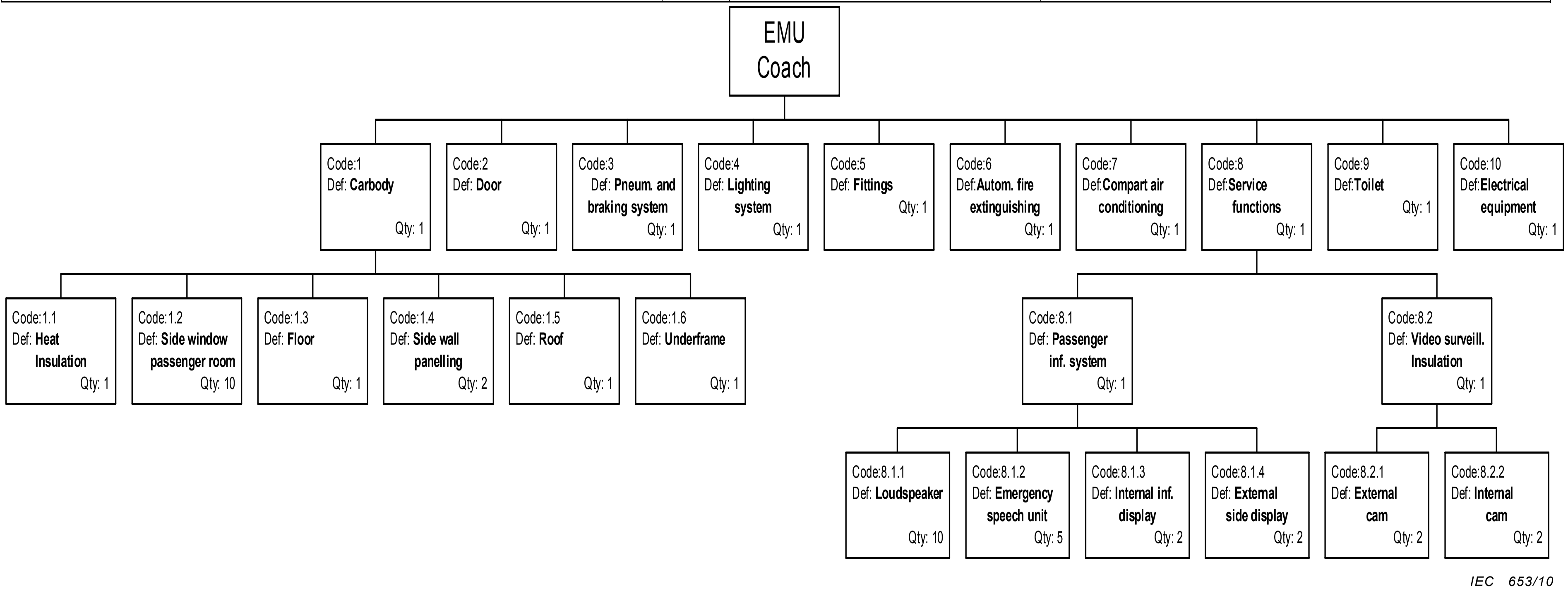

Figure A.1 – Example of physical structure using organisation chart for an Electrical Multiple Unit Coach

TREE BREAKDOWN STRUCTURE			
ROLLING STOCK: EMU COACH		Doc. N.	
		Version Number	
		Date of version	
		Drawn up by	
		Page n/N	
		File name	

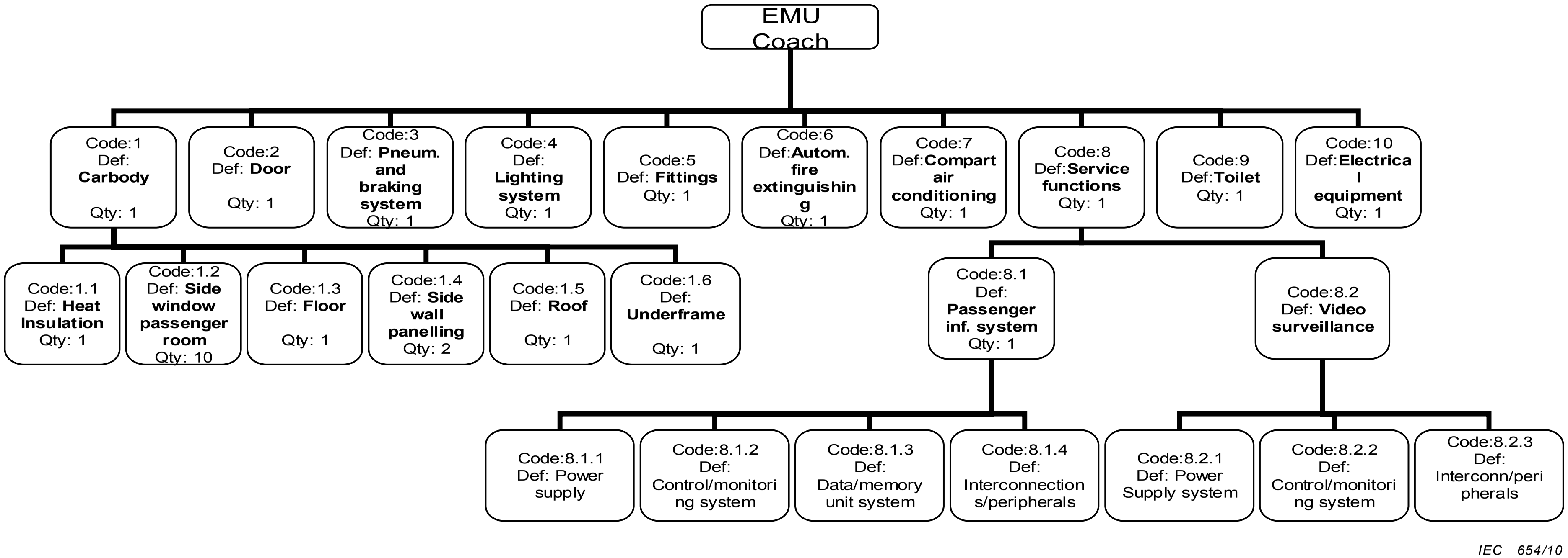

Figure A.2 – Example of functional structure using organisation chart for an Electrical Multiple Unit Coach

The following represents an example of an EMU traction vehicle breakdown structure using a tree diagram.

	TREE BREAKDOWN STRUCTURE							
ROLLING STOCK: EMU TRACTION VEHICLE						Doc. N.		
						Version Number		
						Date of version		
						Drawn up by		
						Page n/N		
						File name		
Code	L1 - System	Qty	Code	L2 - Sub-system or LRU	Qty	Code	L3 - LRU	Qty
1	Carbody	1						
			1.1	Heat insulation	1			
			1.2	Front panel	1			
			1.3	Side window, passenger room	14			
			1.4	Side window, driver's cab	2			
			1.5	Floor	1			
			1.6	Side wall, panelling	2			
			1.7	Roof	1			
			1.8	Nose cover	1			
			1.9	Obstacle deflector	1			
			1.10	Energy absorbtion elements	2			
			1.11	Aerodynamic front nose structure	1			
			1.12	Underframe	1			
2	Motor bogie	1						
			2.1	Bogie frame	1			
			2.2	Carrier	1			
						2.2.1	Steering rod	1
			2.3	Primary suspension	4			
						2.3.1	Damper	1
						2.3.2	Helical spring	1
			2.4	Secondary suspension	1			
						2.4.1	Air spring	2
						2.4.2	Pneumatic components for secondary suspension (set)	1
						2.4.3	Vertical damper	2
						2.4.4	Horizontal damper	2

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Figure A.3 – Example of structure using the tree breakdown chart for an EMU (Electrical Multiple Unit) traction vehicle

			2.5	Bearing assembly	4			
						2.5.1	Bearing box	1
						2.5.2	Bearing	1
			2.6	Wheel set	2			
						2.6.1	Axle	1
						2.6.2	Wheel disk	2
						2.6.3	Brake disk	2
			2.7	Axle gearbox	2			
			2.8	Axle box temperature device	2			
			2.9	INDUSI-magnet	1			
			2.10	Mechanical interface with bodyshell (set)	1			
			2.11	Pneumatic equipment on bogie (set)	1			
			2.12	Speed sensor	2			
			2.13	Brake equipment on the bogie (set)	1			
			2.14	Earthing contacts	2			
3	Trailer bogie	1						
			3.1	Bogie frame	1			
			3.2	Carrier	1			
						3.2.1	Steering rod	1
			3.3	Primary suspension	4			
						3.3.1	Damper	1
						3.3.2	Helical spring	1
			3.4	Secondary suspension	1			
						3.4.1	Air spring	4
						3.4.2	Pneumatic components for secondary suspension (set)	1
						3.4.3	Vertical damper	4
						3.4.4	Horizontal damper	1
			3.5	Bearing assembly	4			
						3.5.1	Bearing box	1
						3.5.2	Bearing	1
			3.6	Wheel set	2			
						3.6.1	Axle	1
						3.6.2	Wheel disk	2
						3.6.3	Brake disk	2

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Figure A.3 *(continued)*

			3.7	Axle box temperature device	2			
			3.8	Mechanical interface with bodyshell (set)	1			
			3.9	Pneumatic equipment on bogie (set)	1			
			3.10	Speed sensor	2			
			3.11	Brake equipment on the bogie (set)	1			
			3.12	Earthing contacts	2			
4	Auxiliary elements on the bogie	1						
			4.1	Sanding device	2			
						4.1.1	Sanding trap	1
						4.1.2	Sanding pipe and nozzles	1
			4.2	Wheel flange lubrication	2			
						4.2.1	Tank	1
						4.2.2	Pump	1
						4.2.3	Magnetic valve	1
						4.2.4	Turbolub distributer	1
						4.2.5	Nozzle	2
						4.2.6	Control unit	1
5	Door	1						
			5.1	Passenger door	2			
						5.1.1	Drive/motor unit	1
						5.1.2	Roller swing arm, right	1
						5.1.3	Roller swing arm, left	1
						5.1.4	Emergency egress device (inside)	1
						5.1.5	Bowden cable, emergency egress device (inside)	1
						5.1.6	Emergency egress device (outside)	1
						5.1.7	Bowden cable, emergency egress device (outside)	1
						5.1.8	Doorleaf, right	1
						5.1.9	Doorleaf, left	1
						5.1.10	Lock box	1
						5.1.11	Light barrier	1
						5.1.12	Control unit	1
			5.2	Internal door	1			
			5.3	External cab door	2			
			5.4	Sliding door driver's cab	1			

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Figure A.3 *(continued)*

6	Draw and buffer gear	1						
			6.1	Automatic coupler	1			
						6.1.1	Coupler head	1
						6.1.2	Uncouple device	1
						6.1.3	Air coupler for main air pipe coupler	1
						6.1.4	Air coupler for uncouple device pipe	1
						6.1.5	Electrical coupler operation device	1
						6.1.6	Coupling rod	1
						6.1.7	Bearing block	1
						6.1.8	Electrical coupler	1
						6.1.9	Covering	1
						6.1.10	Center position	1
						6.1.11	Supplies	1
						6.1.12	Earthing	1
						6.1.13	Coupler head, electrical part	1
			6.2	Coupling link	1			
						6.2.1	Special bearing for articulation	1
						6.2.2	Coupling fork	1
						6.2.3	Guide rod support	1
7	Articulation	1						
			7.1	Articulated damper, rolling	1			
			7.2	Articulated damper, pitching	1			
			7.3	Articulated damper, yawing	1			
			7.4	Intercommunicating gangway	1			
						7.4.1	Bellows	1
						7.4.2	Bellows frame	2
						7.4.2	Step board	1
8	Electrical equipment	1						
			8.1	Traction	1			
						8.1.1	Propulsion inverter boxes	1
						8.1.2	Electric traction motor	2
						8.1.3	Speed sensor for traction control	4
						8.1.4	Traction control unit	1
						8.1.5	Rheostatic breaking resistors	1

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Figure A.3 *(continued)*

			8.2	Auxiliary electrical energy	1			
						8.2.1	LV and MV contactors, relay contactors, fuses, automatic circuit breaker	1
						8.2.2	Battery	1
						8.2.3	Auxiliary static converter with battery charger	1
9	Pneumatic and braking system	1						
			9.1	Brake control device	1			
			9.2	Direct brake control device	1			
			9.3	Electronic control unit	1			
			9.4	Signalling repetition plate	1			
			9.5	Antiskid redounded (1 per axe)	1			
			9.6	Pneumatic group	1			
			9.7	Brake devices group	1			
			9.8	Motor bogie secondary suspension reservoir	1			
			9.9	Trailer bogie secondary suspension reservoir	1			
			9.10	Passenger alarm brake	1			
10	Lighting system	1						
			10.1	Compartment lights	1			
			10.2	Driving cab lights	1			
			10.3	External lights	1			
						10.3.1	White lights	2
						10.3.2	Red lights	2
						10.3.3	Green lights	1
						10.3.4	Central lights	2
11	Fittings	1						
			11.1	Compartment fittings	1			
						11.1.1	Passenger seat	61
						11.1.2	Foldable seat	2
						11.1.3	Manual curtain	18
						11.1.4	Dresshanger (set)	1
						11.1.5	Luggage rack	1
						11.1.6	Hand rails (set)	1
						11.1.7	Litter box	1
						11.1.8	Ticket vending machine	1
						11.1.9	Fire extinguisher	1

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Figure A.3 *(continued)*

			11.2	Driving cab fittings	1			
						11.2.1	Driver seat (adjustable)	1
						11.2.2	Sunshad curtain	3
12	Automatic fire extinguishing	1						
13	Driving cab air conditioning	1						
			13.1	Ventilation	1			
			13.2	Cooling	1			
			13.3	Heating	1			
14	Compart air conditioning	1						
			14.1	Ventilation	1			
			14.2	Cooling	1			
			14.3	Heating	1			
			14.4	Heaters	45			
15	Tachograph device	1						
16	Dead man device	1						
17	Driver's desk	1						
			17.1	Light rack	1			
			17.2	Instruments rack	1			
			17.3	Video surveillance monitor	1			
			17.4	Console	1			
			17.5	Radio equipment	1			
			17.6	ATP equipment	1			
18	Service functions	1						
			18.1	Passenger information system	1			
						18.1.1	Loudspeaker	8
						18.1.2	Controller	1
						18.1.3	Cab Control Unit	1
						18.1.4	Emergency speech unit	4
						18.1.5	Internal information display	2
						18.1.6	External side display	2
						18.1.7	Handset	1
			18.2	Video surveillance system	1			
						18.2.1	External cam	2
						18.2.2	Internal cam	3
						18.2.3	Video monitor	1

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Figure A.3 *(continued)*

19	Washing and wiper system	1			
20	Command & control/diagnostic system				
			20.1	Command & control/diagnostic	1
			20.2	Input/output remoted device	1
			20.3	Diagnostic monitor	1
			20.4	Instruments monitor	1
			20.5	TCN knot	1

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Figure A.3 *(concluded)*

The following (Figure A.4) represents an example of an EMU (Electrical Multiple Unit) coach breakdown structure using a tree diagram.

	TREE BREAKDOWN STRUCTURE							
ROLLING STOCK: EMU COACH						Doc. N.		
						Version Number		
						Date of version		
						Drawn up by		
						Page n/N		
						File name		
Code	**L1 - System**	**Qty**	**Code**	**L2 - Sub-system or LRU**	**Qty**	**Code**	**L3 - LRU**	**Qty**
1	Carbody	1						
			1.1	Heat insulation	1			
			1.2	Side window, passenger room	10			
			1.3	Floor	1			
			1.4	Side wall, panelling	2			
			1.5	Roof	1			
			1.6	Underframe	1			
2	Door	1						
			2.1	Passenger Door	2			
						2.1.1	Drive/motor unit	1
						2.1.2	Roller swing arm, right	1
						2.1.3	Roller swing arm, left	1
						2.1.4	Emergency egress device (inside)	1
						2.1.5	Bowden cable, emergency egress device (inside)	1
						2.1.6	Emergency egress device (outside)	1
						2.1.7	Bowden cable, emergency egress device (outside)	1
						2.1.8	Doorleaf, right	1
						2.1.9	Doorleaf, left	1
						2.1.10	Lock box	1
						2.1.11	Light barrier	1
						2.1.12	Control unit	1
			2.2	Ramp	2			
3	Pneumatic and braking system	1						
			3.1	Production/treatment air group	1			
			3.2	Brake devices group	1			
			3.3	Passenger alarm brake	1			
			3.4	Main reservoir	1			

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Figure A.4 – Example of structure using the tree breakdown chart for an EMU (Electrical Multiple Unit) coach

4	Lighting system	1						
			4.1	Compartment lights	1			
5	Fittings	1						
			5.1	Compartment fittings	1			
						5.1.1	Passenger seat	37
						5.1.2	Foldable seat	12
						5.1.3	Manual curtain	12
						5.1.4	Dresshanger (set)	1
						5.1.5	Luggage rack (set)	1
						5.1.6	Hand rails (set)	1
						5.1.7	Litter box	1
						5.1.8	Fire extinguisher	1
6	Automatic fire extinguishing	1						
7	Compart air conditioning	1						
			7.1	Ventilation	1			
			7.2	Cooling	1			
			7.3	Heating	1			
			7.4	Heaters	45			
8	Service functions	1						
			8.1	Passenger information system	1			
						8.1.1	Loudspeaker	10
						8.1.2	Emergency speech unit	5
						8.1.3	Internal information display	2
						8.1.4	External side display	2
			8.2	Video surveillance system	1			
						8.2.1	External cam	2
						8.2.2	Internal cam	3
9	Toilet	1						
			9.1	Vacuum flush toilet system	1			
			9.2	Water level sensor (Max and Min)	2			
			9.3	Command button	1			
			9.4	Photoelectric sensor	2			
			9.5	Double contact lighting button	2			
			9.6	Piezoresistive sensor	1			
			9.7	Contact probe for liquid level contouring	1			

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Figure A.4 *(continued)*

			9.8	Electropneumatic valve for water	1			
			9.9	Boiler	1			
			9.10	HK toilet door electronic control unit	1			
			9.11	White and black water tank	1			
			9.12	HK wash-basin electronic control unit	1			
			9.13	Interface bus train electronic control unit	1			
			9.14	HK interiors	1			
			9.15	Complete door lock	1			
			9.16	HK automatic door	1			
			9.17	Electric towel	1			
			9.18	WC autocleaning system	1			
10	Electrical equipment	1						
			10.1	Auxiliary electrical energy	1			
						10.1.1	LV and MV contactors, relay contactors, fuses, automatic circuit breaker	1

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Figure A.4 *(concluded)*

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