



## EPD 0009

# RELIABILITY, AVAILABILITY AND MAINTAINABILITY (RAM)

Version 2.0

Issued March 2010

Owner: Manager, Engineering Standards and Configuration

Approved by: Jagath Peiris  
Manager  
Engineering Standards and  
Configuration

Authorised by: Jim Modrouvanos  
General Manager  
Chief Engineers Division

### Disclaimer

This document was prepared for use on the RailCorp Network only.

RailCorp makes no warranties, express or implied, that compliance with the contents of this document shall be sufficient to ensure safe systems or work or operation. It is the document user's sole responsibility to ensure that the copy of the document it is viewing is the current version of the document as in use by RailCorp.

RailCorp accepts no liability whatsoever in relation to the use of this document by any party, and RailCorp excludes any liability which arises in any manner by the use of this document.

### Copyright

The information in this document is protected by Copyright and no part of this document may be reproduced, altered, stored or transmitted by any person without the prior consent of RailCorp.

## Document control

Revision	Date	Summary of change
1.0		First Issue
1.1		Section numbering updated, reference corrections and document control page included
1.2		Replace references to RIC with RailCorp
1.3	June 2007	Appendix 7.4.2 – Sentence altered and bolded. Appendix 1.1.2 – New entry Safe Access. Clause renumbered
2.0	March 2010	3 yearly review, CCB approval on 3 March 2010. Summary of changes as per table below.

## Summary of changes from previous version

Summary of change	Section
Application of new Engineering Procedure format as specified in TMA 400	All
Replace 'major' with 'high complexity' and 'minor' with 'low complexity'	Several
Replace 'integrated support-provision unit' with 'Integrated Support Unit (ISU)' and use of acronym ISU where required	Several
References to appendix reworded	Several
References to other Engineering Procedures – Design are referred to in this document using the new naming conventions (eg, EPD 0001 not EP 0001 P) although not all have been reviewed and renamed as yet. Therefore ED 0014 P now reads EPD 0014 for example.	Several
Introduction – replaced with new text	1
Scope – replaced with new text	2
Referenced documents – updated and documents added	3
Definitions and terms – new definitions added. Definitions of verification and validation refined. Mean active repair time (MART) included as a measure of maintainability.	4
Paragraph 1 replace 'design staff' with 'or on behalf of Rail Corporation NSW'. Paragraph 2 rewording to cover design work done for RailCorp. Requirements for designers to comply with this procedure in specifying RAM and in designing to achieve specified RAM targets included.	5.1
Requirement for specifying RAM was brought forward in the document.	5.2
Requirement to refer to System Assurance Requirements document APP-EX-MN-007 when specifying RAM demonstration requirements in RFTs included.	5.2 & 5.5
Paragraph 1 replace 'iterative' with 'repetitive'. Paragraph 1, dot point 5 combine two sentences into one.	5.2.1
Inserted acronym in title and paragraph 1 instead of full term	5.2.3
Replaced 'design engineers' with 'designers'	5.2.4
Paragraph 3 removed 'Estimates of maintainability (ie'	5.2.5
Availability of Risk division's specialist support in reliability modelling and the availability of the RELEX software tool for modelling mentioned.	5.3.2 & 6.1
Designing for "graceful degradation", including diagnostic and self test functionality and reducing proof test intervals was included.	5.3.4
Specification of data sources to ensure that credible and accurate data will be used was incorporated in requirements	5.5
Wording changes incorporated to clarify relationship with safety	5.6

RAM assurance records – text amended	5.7
RAM assurance records – new subsection added	5.8
Responsibilities – design staff responsibilities amended. ISU and Asset Performance and Reliability Unit staff responsibilities removed.	6
Word targets inserted after RAM in the first sentence to correct previous omission. Replaced ‘design engineers’ with ‘design staff’	6.1
Responsibilities of ISU redefined	6.2
Responsibilities of Asset Performance and Reliability Unit within Asset Planning and Performance division added	6.3
MART included as a measure of maintainability.	A 1.2
Appendix B – RAM assurance records – new appendix identifies what minimum documentary evidence must be produced at each stage of asset lifecycle.	Appendix B

## Contents

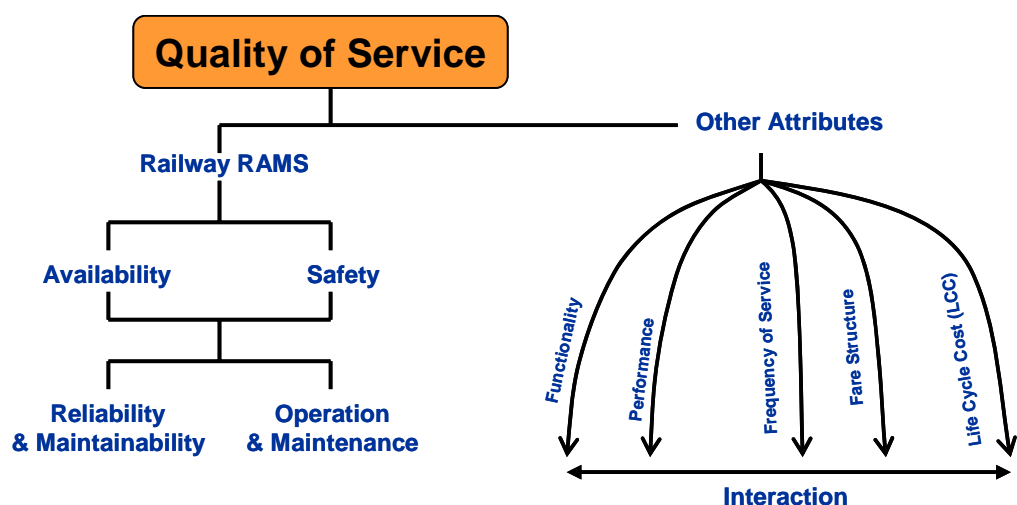
<b>1</b>	<b>Introduction.....</b>	<b>5</b>
<b>2</b>	<b>Scope.....</b>	<b>6</b>
<b>3</b>	<b>Referenced documents.....</b>	<b>6</b>
<b>4</b>	<b>Definitions and terms.....</b>	<b>6</b>
<b>5</b>	<b>Requirements .....</b>	<b>7</b>
5.1	Reliability and maintainability to be performance requirements .....	7
5.2	Specifying RAM.....	8
5.2.1	Reliability design targets .....	8
5.2.2	Maintainability design requirements.....	9
5.2.3	Availability requirements .....	9
5.3	Reliability and maintainability in design .....	9
5.3.1	Reliability .....	9
5.3.2	Reliability modelling.....	10
5.3.3	FMECA.....	11
5.3.4	Reliability improvement during design .....	11
5.3.5	Maintainability.....	11
5.4	Monitoring during design and development.....	12
5.5	Tendering .....	12
5.6	Relationship to safety.....	12
5.7	RAM assurance records.....	13
<b>6</b>	<b>Responsibilities .....</b>	<b>13</b>
6.1	Chief Engineers.....	13
6.2	Design staff .....	13
	<b>Appendix A – Guidelines for specifying RAM design requirements .....</b>	<b>14</b>
	<b>Appendix B – Asset / system lifecycle phase related RAM tasks and assurance records produced in each life cycle phase .....</b>	<b>18</b>

# 1 Introduction

This procedure applies to the management of reliability, availability and maintainability (RAM) of the railway system. RAM is a subset of RAMS which also includes safety. Safety management in design is addressed in procedure EPD 0008.

The goal of the railway system is to achieve a defined level of rail traffic in a given time, safely. RAMS of the rail system describes the confidence with which the system can guarantee the achievement of this goal. It influences the 'quality of service' being delivered to the customer. Quality of service is also influenced by other attributes concerning functionality and performance such as the frequency of service, life cycle costs and fare structures.

This relationship is shown in Figure 1 below.



Adapted from EN 50126:2001

**Figure 1 – - Influence of railway RAMS on Quality of service**

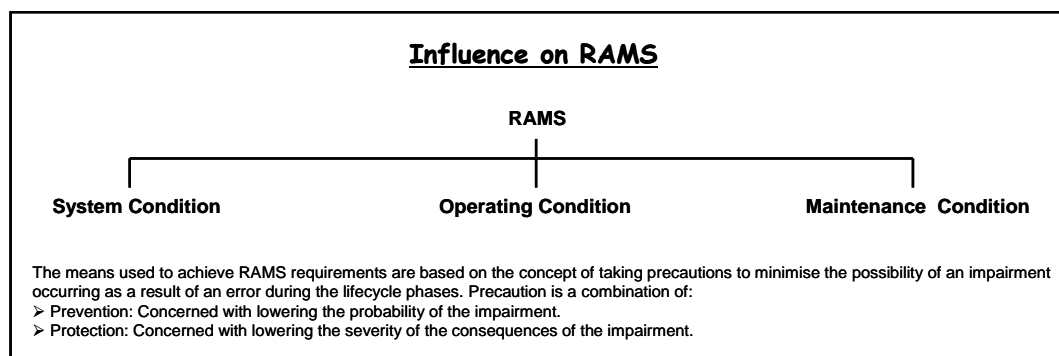
RAMS is a characteristic of a system's long term operation and is achieved by the application of established engineering concepts, methods, tools and techniques throughout the lifecycle of the system. The RAMS of a system can be characterised as a qualitative and quantitative indicator of the degree that the system, or the sub-systems and components comprising that system, can be relied upon to function as specified and to be both available and safe.

Attainment of in-service safety and availability targets can only be achieved by meeting / assuring all reliability and maintainability requirements and controlling the ongoing, long-term, maintenance and operational activities and the system environment.

The RAMS of the railway system is influenced in three ways:

- by sources of failure introduced internally within the system at any phase of the system life cycle (system conditions)
- by sources of failure imposed on the system during operation (operating conditions)
- by sources of failure imposed on the system during maintenance activities (maintenance conditions).

These sources of failure can interact. This relationship is shown Figure 2.



**Figure 2 – - Conditions that Influence RAMS**

## 2 Scope

This procedure sets out the requirements for specifying of Reliability, Availability and Maintainability (RAM) as well as requirements for designing to achieve specified RAM targets. It does not provide detailed instructions for reliability estimation or modelling or for carrying out failure modes, effects and criticality analysis (FMECA) which can be found in the references in Section 3.

## 3 Referenced documents

*APP-EX-MN-004 - RailCorp Total Asset Management (RTAM) Policy Manual*

*APP-EX-MN-007 - Systems Assurance Requirements [Reliability, Availability, Maintainability, and Safety (RAMS); Operations & Maintenance Support (ILS); O&M Life Cycle Costing (LCC)]*

*AS IEC 60300.2—2005 Dependability management—Part 2: Guidance for dependability programme management*

*ISO/IEC 15288: 2008 Systems and software engineering – System Life cycle processes.*

*EN 50126:2001 Railway Applications—Specification and demonstration of reliability, availability, maintainability and safety (RAMS)*

*AS IEC 60812—2002 Analysis techniques for system reliability—Procedure for failure mode and effects analysis (FMEA)*

*RailCorp AM 9995 PM—Maintenance requirements analysis manual*

## 4 Definitions and terms

Refer to EPD 0001 for definitions and terms used in this procedure.

**Reliability** is a characteristic of design. It is defined as the ‘probability that a specified item will perform a specified function within a defined environment, for a specified length of time’. For complex systems the reliability requirement is normally specified in terms of the mean time between failures (MTBF) or as a failure rate, for example failures per million operating hours.

**Availability** is the availability of an item/system is the probability that this item/system will be in a state to perform a required function under given conditions, at a given instant in time or over a time interval, assuming that the given external resources are provided.

Availability is defined by  $A = \text{MUT} / (\text{MUT} + \text{MDT})$  where MUT refers to Mean Uptime and MDT to Mean Downtime.

Depending on what is included in MDT, the availability measured is called **Intrinsic Availability** ( $A_i$ ), **Technical Availability** ( $A_t$ ) or **Operational Availability** ( $A_o$ ).

*Alternatively* **Availability** is the measure of the percentage of time that an item or system is available to perform its designated function. The simplest expression for calculating availability is:

$$\text{availability (A)} = \frac{\text{uptime}}{\text{total time}} \text{ for a continuously operating system}$$

this can also be expressed as:

$$\text{availability (A)} = \frac{\text{total time} - \text{downtime (scheduled + unscheduled)}}{\text{total time}}$$

or in terms of reliability (MTBF) and maintainability (MTTR) measures as:

$$\text{availability (A)} = \frac{\text{MTBF}}{\text{MTBF} + \text{MTTR}}$$

**Maintainability** is the probability that a given active maintenance action, for an item under given conditions of use can be carried out within a stated time interval when the maintenance is performed under stated conditions and using stated procedures and resources (IEC 60050-191).

*Alternatively* **Maintainability** is a characteristic of design and is essentially a measure of the ease with which the item can be maintained. A more formal definition is 'maintainability is a characteristic of design and installation, expressed as the probability that an item will be restored to operating condition, within a given period of time, using prescribed procedures and resources. The most commonly used measure of maintainability is the mean time to repair (MTTR). Where the logistical delays aren't considered and the time of interest is the time actively spent in repairing the system maintainability can be measured as mean active repair time (MART).

**RAM Allocation / Apportionment** is the process whereby the RAMS elements for a system are subdivided between the various items which comprise the system to provide individual targets.

**Verification** is the process of checking that a product service or system meets its specified requirements.

**Validation** is the process of establishing evidence that a product, service or system accomplishes its intended use or application.

## 5 Requirements

### 5.1 Reliability and maintainability to be performance requirements

Unless otherwise approved by the appropriate discipline Chief Engineer, Reliability and maintainability shall be treated as key performance requirements in all new design work carried out by or on behalf of Rail Corporation NSW (RailCorp). Specific reliability and maintainability design criteria should be included in all engineering specifications developed for new equipment and in modifications to existing equipment.

The levels of reliability and maintainability that are built in to the initial design not only govern the level of availability that can be achieved in service but also have a major influence on the cost of maintenance over the life of the asset. For this reason it is essential that all infrastructure equipment that is designed for RailCorp or is specified for

procurement as a standard item should incorporate the best possible levels of reliability and maintainability commensurate with the acceptable cost for the item.

Designers shall:

- when preparing an Engineering Specification / Design Brief, use this procedure in conjunction with the referenced standards and documents to specify RAM targets that meet the customer requirements for availability of the system to perform the intended functions of the system at the required levels;
- when designing asset systems to achieve specified RAM targets, use this procedure in conjunction with the referenced standards and documents to design and demonstrate that the specified RAM targets can be achieved through the proposed design and to include RAM validation requirements in the subsequent phases of the asset / system lifecycle in RFTs.

## 5.2 Specifying RAM

Designers may be required to develop RAM requirements for inclusion in engineering specifications under two main sets of circumstances:

- where an internal specification is being prepared for commercially available equipment to meet a specific purpose or for type testing and approval, or
- a specification is being prepared for another, external organisation to complete a design task, generally through a request for tender (RFT).

Two different approaches can be taken for specifying RAM requirements for new equipment as follows:

- specific reliability and maintainability requirements may be included within the specification, or
- an availability target may be specified, which can be met by different combinations of reliability and maintainability.

Design targets shall be included in the specification and then monitored throughout the design stages of the project with either approach if the required outcomes are to be achieved in the final design.

The following subsections provide an outline of key points. Appendix A of this procedure includes more detailed information on each aspect, together with sample clauses for specifications and inclusion in RFTs. Designers when specifying RAM for design and construct / manufacture and supply contracts should also refer to *System Assurance Requirements (RAMS, ILS, O&M LCC) – APP-EX-MN-007* for specification clauses for Reliability /Availability Demonstration Testing (RADT) and Maintainability Demonstration Testing (MDT) for the type of assets / systems to be purchased for RailCorp.

### 5.2.1 Reliability design targets

Reliability targets will have a major influence on the type and quality of items selected as part of the design. It is important to ensure that the specified level of performance is not excessive to avoid conflict between reliability requirements and other specification requirements. This is particularly true if specific equipment is nominated which cannot meet the required level of reliability.

The approach taken is dependent on the type of equipment involved. The form of specification for functional equipment is not generally appropriate for fixed mechanical structures. Examples of each type of specification are in appendix A.



## 5.2.2 Maintainability design requirements.

Maintainability design requirements are included in the specification to establish the type of features to be incorporated within the design to ensure that the infrastructure can be maintained safely and efficiently. Appendix A contains some examples of important design aspects for consideration in developing the specification.

It should be noted that maintainability is not the same as scheduled maintenance requirements, which cover specific tasks designed to maintain the infrastructure in good condition. Maintainability characteristics are an integral part of the design and govern the ease and safety and economy with which maintenance tasks, scheduled and unscheduled, can be performed. Development of maintenance tasks and technical maintenance plans (TMP) should be covered separately within the statement of work for the task.

## 5.2.3 Availability requirements

Availability provides the single measure of utility for an infrastructure item or system, assuming that the operating performance is satisfactory, ie. it produces the required output or performs the required functions. It provides a target for the amount of time the system is to be available for operational use.

In order to specify an availability requirement the designer shall:

- specify the percentage availability required
- establish the duty cycle for the equipment ie the number of hours per day it is needed for use if available
- define the conditions under which the system can be assessed as being “available” and “unavailable” respectively.

Availability targets may be used as an alternative to specifying separate reliability and maintainability targets although a requirement to incorporate general maintainability features can be included in addition to availability targets. Appendix A contains additional information on availability specifications.

## 5.3 Reliability and maintainability in design

Ensuring that new designs meet reliability and maintainability targets requires careful selection of equipment, materials and design architecture combined with progressive estimation and verification of the predicted performance during the design phase. It is not enough to finalise and build the design and then to operate or test to establish the level of reliability or maintainability that has been achieved. This after the event approach is unlikely to achieve the desired result.

### 5.3.1 Reliability

Designing for reliability is essentially a repetitive process. It involves several key steps that are applicable for all high and low complexity design projects as follows:

- Determine the targets or level of performance to be achieved. This should normally be included in the engineering specification and is typically specified at major system or installation level eg track, signalling, DC traction or tunnel ventilation system.
- Establish a mathematical model/s to represent the architecture selected for the design. This can be used to test the predicted performance of selected equipment against target levels.
- Allocate targets to progressively lower levels within the design architecture. The ultimate requirement is to establish the predicted level of reliability or maintainability

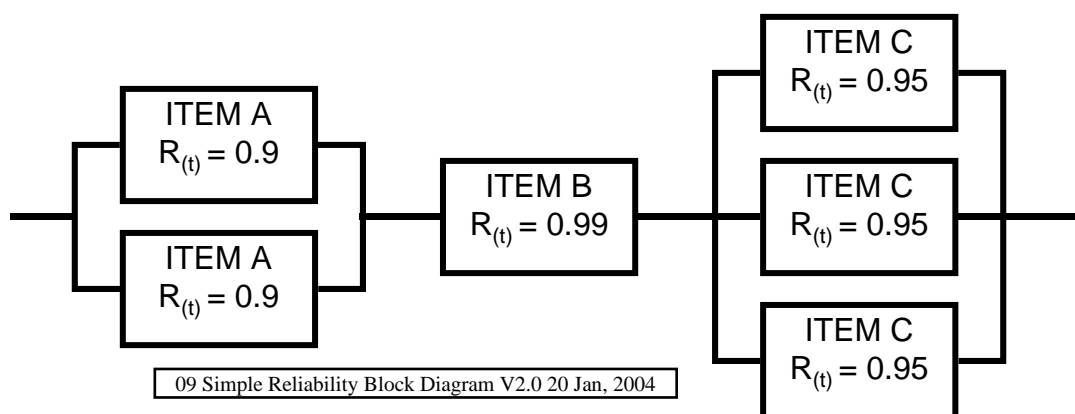
characteristic for each major item or groups of items such as OHW section insulators. Targets established for systems, sub-systems and individual items are commonly referred to as reliability budgets.

- Select equipment based on established targets.
- Test the predicted level of performance against targets and identify shortfalls.
- Introduce improvements to the design or to the proposed architecture to meet the required target.

### 5.3.2 Reliability modelling

Reliability modelling and estimation techniques are applicable to all but simple design tasks where reliability improvement may not be a primary objective. This should be accomplished progressively during the preliminary and detailed design stages to provide the opportunity to identify shortfalls against reliability targets and to take corrective action.

Reliability modelling is a specialised field and a detailed explanation of the available techniques is outside the scope of this procedure. The modelling process may range in complexity from manual calculations using block diagrams to complex computer models but will involve preparation of one or more reliability block diagrams to serve as a basis for modelling and prediction. Figure 3 – illustrates a simple block diagram.



**Figure 3 – - Simple reliability block diagram**

The primary responsibility for RAM performance of designs rests with the designer. For high complexity projects designers shall seek specialised support to undertake reliability modelling. RailCorp Risk division has obtained licences for using of the RELEX software package that can be used for this purpose and specialist support is available to designers through Risk division to undertake this task. The designers shall ensure that:

- the mathematical reliability model is representative of the actual design of the system being synthesized
- selection of equipment and other relevant changes in the design architecture is promptly advised to the specialised resource used in modelling
- failure rate data to be used in the model is derived from the best available source and is consistent with the intended environment in which the item is to be used. Data may either be from manufacturer's predictions for new equipment or from the failure database available for RailCorp equipment or a combination of the two
- data used in the modelling and estimation process is representative for the intended use of the equipment. Estimates obtained from manufacturers for new equipment or data for existing items that are to be used in a more severe environment may need to be factored or derating factors applied to ensure that it is representative.

Reliability reports and models developed as part of the design process shall be maintained as part of the design record for the equipment.

### 5.3.3 FMECA

FMECA is described in more detail in *EPD 0019* where it forms an integral part of the process of determining scheduled maintenance requirements. However, FMECA also provides a direct means of verifying failure data and assumptions used in reliability modelling and should normally be carried out in conjunction with the modelling task.

While FMECA carried out as part of the design process varies from that carried out as part of maintenance requirements analysis, mainly in terms of the scope and level of detail at which failures are considered, failure rates are common to both FMECA assessment and the reliability model. In addition FMECA provides a means of verifying that all relevant failure modes have been considered during the modelling process.

### 5.3.4 Reliability improvement during design

Corrective actions may be required in cases where the predicted reliability falls short of the required level of performance or where FMECA or hazard analysis reveals the existence of critical failure modes. Potential sources of improvement include:

- replacing the item initially selected as part of the design with a different item having better reliability characteristics
- changing the design to reduce the reliance on items that have relatively low levels of reliability if an improved item is not available or would lead to an unacceptable increase in cost
- introducing redundancy in critical applications, where it is possible to do so.
- Designing for “graceful degradation”, including diagnostic and self test functionality and reducing proof test intervals

Selection of potential methods of improving reliability is a direct responsibility of designers.

### 5.3.5 Maintainability

Maintainability requirements shall be included in the specification either directly in the form of MTTR targets for specific equipment or in general terms such as a requirement to perform all scheduled maintenance during access windows that may directly influence characteristics of the design. These may include tolerance to failures through the incorporation of redundant features (which also affect reliability performance) and/or fault diagnosis methods and accessibility features to permit rapid isolation and correction of problems.

Maintainability characteristics are typically assessed through a systematic review of the design, to assess infrastructure support requirements including fault finding, scheduled maintenance and repair/replacement and to identify areas that do not meet the general criteria included in A-1.2 of Appendix A. The key consideration in each case is to assess how a task may be accomplished and the safety and efficiency with which it may be performed.

MTTRs are also used in conjunction with reliability predictions to assess the likely availability of the system. Clear definition of the rules for measuring MTTR are essential where the parameter is used for this purpose, or in any situation where achievement of specific MTTR values forms part of the design validation process.

The most appropriate definition of MTTR for validation purposes is that it includes only the time taken for direct fault finding and repair of faults. Administrative components of

total downtime, such as the delay in attending a fault or time awaiting spares or other resources, are generally outside of the control of designers and are normally excluded from the estimates of MTTR.

## 5.4 Monitoring during design and development

Monitoring of reliability predictions during design and development projects is an integral part of the design verification process. This may involve preparation of reports, review of modelling results and in some cases the planning of demonstrations to verify that maintainability requirements can be achieved. *EPD 0011* includes specific requirements for design verification.

## 5.5 Tendering

Equipment reliability or availability is to be used as a selection criterion for new equipment wherever possible. This typically forms part of the life cycle cost assessment carried out in the tender selection phase to establish the alternative which will provide the lowest cost of ownership over the expected life of the infrastructure.

The following requirements should be considered for inclusion in the tender documentation in support of the reliability program:

- a requirement for the design contractor to develop reliability models for nominated sections of the design and to report on the predicted reliability for the infrastructure in advance of technical reviews
- a requirement for the tenderer to provide specific reliability information for the product offered in response to the RailCorp specification
- a requirement for specification of data sources to ensure that credible and accurate data will be used
- a requirement for the contractor to complete and deliver a FMECA which will be used to validate reliability models to support safety and hazard analysis and as a basis for establishing programmed maintenance requirements
- an availability model that takes account of predicted reliability and maintainability characteristics (reactive repair times as well as completion times for scheduled maintenance inspections).

Additional information should be requested as part of the tendering process to provide a basis for comparative assessment of bids received. Appendix A contains sample clauses for inclusion in the RFT. Further RAM performance and demonstration requirements for inclusion in RFTs are available in *System Assurance Requirements (RAMS, ILS, O&M LCC) – APP-EX-MN-007*.

## 5.6 Relationship to safety

System RAM and system safety performance are closely associated and shall be considered in conjunction when specifying design targets. This linkage is illustrated through the use of FMECA which represents a key input for both reliability/maintenance requirements analysis and hazard and risk analysis processes.

FMECA involves the systematic identification of potential failures. Each type of failure is then evaluated for its effect on system operation, safety and the environment. Failures that involve an unacceptable level of risk to people, other system assets or the environment should be corrected or improved so that the chance of failure and the consequences if one occurs are within acceptable levels. This may require the introduction of a reliability improvement change.

FMECA is intended to examine the interface between operator or maintenance staff and the systems being designed to identify hazardous operations. Where the design has introduced a new hazard corrective action shall be taken. *EPD 0008* describes the hazard and risk analysis process that addresses requirements for safety considerations during the design phase.

## **5.7 RAM assurance records**

Appendix B provides a summary asset / system life cycle phase related RAM tasks and assurance records that shall be produced and kept for each lifecycle stage.

# **6 Responsibilities**

## **6.1 Chief Engineers**

Chief Engineers shall approve the RAM targets as part of the approval of the design brief / engineering specification. Reference Clause 5.1, where a standard design solution with inherent RAM qualities is proposed, the appropriate Chief Engineer may waive the requirement for a complete RAM analysis.

## **6.2 Design staff**

Design staff shall either specify RAM targets or design to meet specified RAM targets whichever the case may be in accordance with procedure. Design staff shall ensure traceability records are maintained throughout specification development or during design for RAM related tasks.

Where specialist skills and knowledge are required for performing the analysis and modelling, designers shall seek expert assistance. Risk division has obtained licences for RELEX software that can be used for modelling and specialist support is available to designers through the Risk division in undertaking this task. Some assistance in the form of advice to internal RailCorp design staff may be available from the Integrated Support Unit within the Professional Services Division and from the Asset Performance and Reliability Unit with the Asset Planning and Performance Division.

## Appendix A – Guidelines for specifying RAM design requirements

### A-1 Specification requirements

#### A-1.1 Reliability design requirements

The following paragraphs provide information on reliability specifications for functional items and fixed mechanical items/structures respectively.

##### A-1.1.1 Functional item reliability

Specific reliability requirements for functional items should normally be included in the specification. This may be expressed in the form of MTBF (as below) or by any other suitable measure.

*The infrastructure (or item) shall exhibit a mean time between failures (MTBF) of not less than “X” hours in the specified operating environment.*

This method of specification may be used for individual infrastructure items, eg a transformer, points machine, extraction fan or may be applied for the entire installation covered by the specification, eg signalling or communications sub-system. Where a target is specified for an installation the achieved result can only be assessed through some form of modelling, covered in 5.3.2 of this procedure.

Selection of the target reliability is a key issue in determining specification requirements. To the maximum possible extent this should be chosen to reflect a high standard of performance but should be realistic for the type of equipment covered by the specification and should take account of the likely costs of over specification.

Target values may be established by reviewing product specifications from suppliers or by assessing the performance of existing infrastructure and applying an incremental improvement for advances in technology since the existing equipment was supplied. Above all the targets should be set in recognition of the intended use and criticality of the equipment for safety or operational performance.

Specifying high levels of reliability will generally lead to an increase in the initial acquisition cost since the equipment will normally be of higher quality to achieve the required level of reliability. However, this increase in initial cost will generally be offset or exceeded by savings in operating and maintenance costs for the equipment and will represent a cost effective solution over the equipment life cycle. The appropriate balance between reliability and cost can be established through life cycle cost (LCC) modelling and assessment for non-critical items.

##### A-1.1.2 Fixed mechanical items/structures

The specification of an MTBF is not generally applicable for fixed mechanical installations such as pipe work and structures. This type of equipment tends to deteriorate progressively over a relatively long period and does not exhibit the same types of failure patterns as functional items. However, detailed reliability information is available for other types of fixed installations such as track and OHW catenary which can be regarded as functional equipment.

Reliability criteria for fixed installations are normally specified in terms of a minimum replacement life, coupled with appropriate maintainability features designed to prolong the service life of the equipment. The requirement for a minimum replacement life may be specified in the general form:



*The design of the infrastructure shall be capable of achieving a total installed life of not less than "X" hours/ years/cycles prior to inspection or replacement.*

## A-1.2 Maintainability design requirements

Maintainability characteristics should be included in the engineering specification as either essential or desirable features as appropriate. This will usually involve specific considerations such as:

- **safe access** - this requirement applies only to the location and orientation of equipment with respect to the defined danger zone within the rail corridor. The manufacture and installation design of equipment, where practicable, must allow personnel to work outside the danger zone and not work with their backs to the danger zone.
- **accessibility** - this may include inspection points, swing out racks, quick release covers and similar features aimed at providing rapid access to equipment which requires routine maintenance inspection, cleaning or replacement (such as filters), without the need for special tools or equipment.
- **interchangeability** - this covers both the ability to use a range of standard replacement items without special fitting, adjustment or alignment and the level at which interchangeability is required, eg part or sub-assembly.
- **self-diagnostic features (built-in-test) / condition monitoring** - this covers the type and level of capability required to diagnose faults or to monitor the condition or performance of equipment without disassembly. Features may include test points or built in software for monitoring purposes or sampling provisions. The extent of coverage, or the probability of detection of an unsatisfactory condition, represents an additional level of specification which may be appropriate for development contracts, or which may be requested for off-the-shelf solutions.
- construction features - examples include:
  - modular construction of electronics and other equipment to permit easy removal and replacement of repairable components. Isolation for replacement is a further consideration for some types of equipment
  - visible fault indicators which assist in physical monitoring or repair of equipment
  - types of material to be used to withstand the products to be processed
  - protective finishes and corrosion protection
- **compatibility** - this requirement may be used to specify the need for compatibility with existing major facilities where the new equipment is to be interfaced to existing infrastructure or for existing support equipment and skills available within RailCorp.
- **handling provisions** - this may include provisions such as lifting lugs for removal/replacement of heavy items or assemblies, fork-lift compatibility and lifting limitations for manual handling.
- **adjustment and alignment** - provisions for adjustment or alignment of equipment either to take account of routine wear or following removal and installation of replacement items such as couplings and drive shafts.

The preceding characteristics represent typical considerations needed for efficient monitoring and maintenance of the infrastructure. Maintainability requirements can also be specified in the form of a MTTR or MART. MTTR requirements should be considered for inclusion in the specification where an item is critical and must be replaced quickly to get the infrastructure back on line after a failure occurs.

Different MTTR requirements may need to be specified for different items or parts of the infrastructure. For example, an MTTR of 15 minutes may be appropriate for an electronic control system incorporating full built in test and modular construction, but will not be appropriate for replacement of a section of track because of a weld failure or cracking.

MTTR requirements can generally be specified in the form:

*The equipment shall exhibit a MTTR of X minutes/hours with a maximum time to repair of no more than X minutes/hours.*

## A-1.3 Availability

Availability requirements are normally specified in the following form:

*The infrastructure (or equipment) shall be capable of achieving an availability of not less than "X" % when operated and maintained within the specified environment and in accordance with the manufacturers' recommendations.*

Defining when a system is available is essential for both design purposes and for assessment of whether the target has been met. This is especially important when the infrastructure or equipment incorporates redundancy or other features that may enable it to operate at a reduced level of performance after an initial failure has taken place.

The definition of availability should then include:

- functions that are essential for the equipment to be classed as available
- conditional failures which define conditions under which the equipment may be assessed as capable of performing the primary function and thus available even though a failure has taken place and performance is degraded. This may include operation in a manually controlled mode when the normal mode is automatic control, or operation at a reduced level of performance such as reduced speed limit. A maximum period can be specified for operation in this condition if required.

The purpose of the specification is to achieve a solution that will be both capable and reliable over a long period. Relaxation of any factors that reduce the potential availability should be approached cautiously at the RFT stage and may lead to an unacceptable result. Conversely, specifying unrealistically high targets and requirements, such as the requirement for every function to work perfectly for the infrastructure to be regarded as available, may increase cost with no real benefit.

The percentage availability can then be established to be consistent with the availability definition used. If availability has been defined on the basis of all functions operating, ie no failures at all, setting a very high target, eg 0.999 (99.9%) may not be realistic. This requires an average total downtime for both scheduled maintenance and reactive tasks of about 40 minutes per month assuming continuous operation.

Alternatively, a target of 0.99 (99.0%) yields a permissible average downtime of about 7 hours per month (noting that this represents a long term average downtime if the infrastructure is used continuously.) This may not be acceptable for equipment that must operate for 24 hours per day, but may be acceptable if a daily maintenance window is allowed for any scheduled checks and correction of failures. The actual target to be specified depends to a large extent on an assessment of the acceptable level of downtime for the specific system or equipment involved.

When establishing availability targets for infrastructure installations it must be recognised that the availability for the installation will be the product of the availability for the individual sub-systems. This should be taken into account in establishing availability targets for inclusion in the specification.

For example, if the system contains three sub-systems which must all be operating for the infrastructure to be operable the availability for the complete system will be:

*= availability (sub-system 1) X availability (sub-system 2) X availability (sub-system 3)*



For systems which are used in a stand-by mode, or where the duty cycle is not continuous, time required to reach full operation from either a cold start or stand-by mode should be considered for inclusion within the availability specification. As with the availability target this requirement should reflect a realistic assessment of the circumstances likely to be encountered and may then be included as a design verification requirement within the system test plan.

Including an availability target within a specification imposes practical constraints on both the reliability and maintainability characteristics of equipment to be provided. As can be seen from the equations in 4 of this procedure the required level of availability can be achieved by different combinations of reliability (MTBF) and maintainability (MTTR) but both must achieve satisfactory levels to meet the intent of the specification.

## **A-1.4 Additional information - RFT**

Additional information shall be requested as part of the tendering process, to provide a basis for comparative assessment of bids using equivalent information for each option.

The following sample clause may be modified as appropriate to cover this requirement within the RFT or specification:

*The items supplied shall exhibit a high level of reliability, consistent with the achievement of availability targets specified for the infrastructure. Tenderers shall provide details of the reliability claimed for each major element of the offered equipment in the specified operating environment including the source of reliability data. If claimed reliability performance is based on calculation, the basis and methodology for the calculation should be quoted. If based on actual field operating performance, the source of the data, including details of the installation and, where possible, methods of verification should be provided.*

*Reliability performance is to be expressed in the form of a mean time between failure (MTBF), where a failure is defined as a condition which will prevent the item performing its intended primary functions.*

The RFT should also seek information on the specific maintainability features incorporated in the equipment offered by tenderers. MTTR data should be requested irrespective of whether specific requirements have been included in the specification. A typical clause for inclusion in the tender documents is as follows:

*Tenderers are to provide information on specific maintainability features included in the design and are to provide typical and average times needed to replace major replaceable items (including test where necessary) and to perform routine inspection and replacement of consumable items such as filters.*

*Estimates should include a clear statement about whether the MTTRs quoted include any allowance for response times and waiting times to obtain suitable spares and other equipment necessary for the task.*

## Appendix B – Asset / system lifecycle phase related RAM tasks and assurance records produced in each life cycle phase

Standard system life cycle engineering model core elements	System life cycle engineering processes	RTAM technical process model elements	Technical process elements summary objectives (ISO/IEC 15288 based)	Phase related RAM tasks (EN 50126 based)	Assurance record
Need	Definition of need	Customer / stakeholder requirements (service delivery requirements) and Asset strategic planning	To establish the asset portfolio that most appropriately, effectively and efficiently meets service delivery requirements.	As defined in stakeholder requirements.	<ul style="list-style-type: none"> <li>User requirement / Customer specification with RAM requirements specified in broad terms for the project.</li> </ul>
Concept	Conceptual design	Asset requirements management	To define the requirements for a system that can provide the services needed by users and other stakeholders in a defined environment and to transform the stakeholder, requirement-driven view of desired services into a technical view of a required product that could deliver those services.	<ul style="list-style-type: none"> <li>Review previously achieved RAM performance</li> <li>Consider RAM implications of project</li> <li>Evaluate past experience data for RAM</li> <li>Perform preliminary RAM analysis</li> <li>Set RAM policy</li> <li>Identify long term operations &amp; maintenance conditions</li> <li>Identify influence on RAM of existing infrastructure constraints</li> </ul>	<ul style="list-style-type: none"> <li>Preliminary RAM analysis report containing <ul style="list-style-type: none"> <li>Historic RAM data used in analysis</li> <li>RAM impact assessment of project on overall system</li> <li>RAM concept adopted for the project</li> </ul> </li> <li>Engineering Specification containing <ul style="list-style-type: none"> <li>RAM targets for various systems, subsystems and components of the project.</li> </ul> </li> </ul>

Standard system life cycle engineering model core elements	System life cycle engineering processes	RTAM technical process model elements	Technical process elements summary objectives (ISO/IEC 15288 based)	Phase related RAM tasks (EN 50126 based)	Assurance record
Specify	Preliminary design & detailed design and development	Asset design & standards management	<p>To encapsulate and define areas of solutions expressed as a set of separate problems of manageable, conceptual and ultimately realisable proportions.</p> <p>To identify and explore one or more implementation strategies at a level of detail consistent with the system's technical and commercial requirements and risks.</p> <p>To define the design solution in terms of the requirements for the set of system elements from which the system is configured and use the resulting specified design requirements as the basis for verifying the realised system and for devising an assembly and verification strategy.</p>	<ul style="list-style-type: none"> <li>Specify system RAM requirements (overall) specify system RAM requirements (overall)</li> <li>Define RAM acceptance criteria (overall)</li> <li>Define system functional structure</li> <li>Establish RAM programme</li> <li>Establish RAM management <ul style="list-style-type: none"> <li>- apportion system RAM requirements</li> <li>- specify sub-system &amp; component RAM requirements</li> </ul> </li> <li>Define sub-system &amp; component RAM acceptance criteria</li> <li>Define sub-system &amp; component RAM acceptance criteria.</li> <li>Implement RAM programme by review, analysis, testing and data assessment covering: <ul style="list-style-type: none"> <li>- reliability &amp; availability</li> <li>- maintenance &amp; maintainability</li> <li>- optimal maintenance policy logistic support</li> </ul> </li> <li>Undertake programme control covering: <ul style="list-style-type: none"> <li>- RAM programme management</li> <li>- control of sub-contractors &amp; suppliers</li> </ul> </li> </ul>	<ul style="list-style-type: none"> <li>RAM requirements allocation matrix showing allocation of RAM targets to various sub-systems and components of design</li> <li>Technical requirements specification containing <ul style="list-style-type: none"> <li>RAM performance criteria and adopted RAM policy for the project</li> <li>Requirements for meeting RAM targets, methods of evaluation and acceptance criteria for various systems, sub-systems and components of the project.</li> </ul> </li> </ul>
Acquire	Construction and decommissioning	Asset delivery management	<p>To establish and evolve project plans, to execute the project plans, to assess actual achievement and progress against the plans and to control execution of the project through to fulfilment.</p> <p>To define the activities necessary to establish an agreement between two or more organisations (alliance delivery, PPP, TIDC interface etc.) to acquire products to be used as an operational system or of elements of a system being developed by a project or supply a product or service that is delivered to the acquirer.</p>	<ul style="list-style-type: none"> <li>Perform environmental stress screening</li> <li>Perform RAM improvement testing</li> <li>Commence failure reporting and corrective action system (FRACAS)</li> <li>Start maintainer training</li> <li>Establish spare parts and tool provision</li> <li>Perform RAM demonstration</li> <li>Assess RAM demonstration</li> </ul>	<ul style="list-style-type: none"> <li>System RAM performance records</li> <li>FRACAS data</li> <li>Training records for maintainers</li> <li>Lists of spare parts and tools provided in accordance with RAM policy adopted</li> <li>O&amp;M manuals</li> <li>TMPs and maintenance schedules</li> </ul>
Operate / maintain	Utilisation and support	Asset maintenance management	To establish processes to monitor the system's capability to deliver services, record problems for analysis, take corrective, adaptive and preventive actions and confirm restored capability.	<ul style="list-style-type: none"> <li>Ongoing procurement of spare parts &amp; tools</li> <li>Perform ongoing reliability centred maintenance logistic support</li> <li>Consider RAM implications for modification &amp; retrofit</li> </ul>	<ul style="list-style-type: none"> <li>Competency records of maintainers</li> <li>Operation &amp; maintenance records</li> <li>Failure and repair records</li> <li>RAM performance analysis records.</li> </ul>

Standard system life cycle engineering model core elements	System life cycle engineering processes	RTAM technical process model elements	Technical process elements summary objectives (ISO/IEC 15288 based)	Phase related RAM tasks (EN 50126 based)	Assurance record
Dispose	Retirement and disposal	Asset disposal management	<p>To establish processes to deactivate, disassemble and remove the system and any waste products consigning them to a final condition and returning the environment to its original or an acceptable condition.</p> <p>To establish processes to destroy, store or reclaim system entities and waste products in an environmentally sound manner in accordance with legislation, agreements, organizational constraints and stakeholder requirements. Where required, maintain records in order that the health of operators and users and the safety of the environment can be monitored.</p>	<ul style="list-style-type: none"> <li>No activity for RAM</li> </ul>	
		Asset performance management	<p>To collect, analyse and report data relating to the products developed and processes implemented within the organization, to support effective management of the processes and to objectively demonstrate the quality of the products and to ensure system integrity is maintained at all times.</p> <p>To carry out post implementation reviews to collect and utilise the knowledge learned throughout a project to optimise the delivery and outputs of projects in the future.</p>	Collect, analyse, evaluate and use performance & RAM statistics	<ul style="list-style-type: none"> <li>RAM performance data</li> </ul>