

Railway applications — The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS) —

Part 1: Basic requirements and generic process

ICS 45.020

National foreword

This British Standard is the UK implementation of EN 50126:1999, incorporating corrigenda May 2006 and May 2010.

The UK participation in its preparation was entrusted to Technical Committee GEL/9, Railway electrotechnical applications.

A list of organizations represented on this committee can be obtained on request to its secretary.

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English version

**Railway applications –
The specification and demonstration of
Reliability, Availability, Maintainability and Safety (RAMS)
Part 1: Basic requirements and generic process**

Applications ferroviaires –
Spécification et démonstration
de la fiabilité, de la disponibilité,
de la maintenabilité et de la sécurité
(FDMS)
Partie 1: Exigences de base et procédés
génériques

Bahnanwendungen –
Spezifikation und Nachweis
der Zuverlässigkeit, Verfügbarkeit,
Instandhaltbarkeit, Sicherheit (RAMS)
Teil 1: Grundlegende Anforderungen und
genereller Prozess

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart, 36 B-1050 Brussels

Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 9X, Electrical and electronic applications in railways.

The text of the draft was submitted to the formal vote and was approved by CENELEC as EN 50126 on 1998-10-01.

The following dates were fixed:

- latest date by which the EN has to be implemented
at national level by publication of an identical
national standard or by endorsement (dop) 2000-04-01
- latest date by which the national standards conflicting
with the EN have to be withdrawn (dow) 2000-04-01

To assist the user in the application of this standard for safety and for managing RAM performance in the rolling stock procurement process, the following application guides have been produced:

CLC/TR 50126-2 ¹⁾ Guide to the application of EN 50126-1 for safety

CLC/TR 50126-3 Guide to the application of EN 50126-1 for rolling stock RAMS

Annexes designated “normative” are part of the body of the standard.

Annexes designated “informative” are given for information only.

In this standard, annexes A to E are informative.

¹⁾ In preparation.

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Introduction

This European Standard provides Railway Authorities and the railway support industry, throughout the European Union, with a process which will enable the implementation of a consistent approach to the management of reliability, availability, maintainability and safety, denoted by the acronym RAMS. Processes for the specification and demonstration of RAMS requirements are cornerstones of this standard. This European Standard aims to promote a common understanding and approach to the management of RAMS.

This European Standard can be applied systematically by a railway authority and railway support industry, throughout all phases of the lifecycle of a railway application, to develop railway specific RAMS requirements and to achieve compliance with these requirements. The systems-level approach defined by this European Standard facilitates assessment of the RAMS interactions between elements of complex railway applications.

This European Standard promotes co-operation between a railway authority and railway support industry, within a variety of procurement strategies, in the achievement of an optimal combination of RAMS and cost for railway applications. Adoption of this European Standard will support the principles of the European Single Market and facilitate European railway inter-operability.

The process defined by this European Standard assumes that railway authorities and railway support industry have business-level policies addressing Quality, Performance and Safety. The approach defined in this standard is consistent with the application of quality management requirements contained within the ISO 9000 series of International standards.

1 Scope

1.1 This European Standard:

- defines RAMS in terms of reliability, availability, maintainability and safety and their interaction;
- defines a process, based on the system lifecycle and tasks within it, for managing RAMS;
- enables conflicts between RAMS elements to be controlled and managed effectively;
- defines a systematic process for specifying requirements for RAMS and demonstrating that these requirements are achieved;
- addresses railway specifics;
- does not define RAMS targets, quantities, requirements or solutions for specific railway applications;
- does not specify requirements for ensuring system security;
- does not define rules or processes pertaining to the certification of railway products against the requirements of this standard;
- does not define an approval process by the safety regulatory authority.

1.2 This European Standard is applicable:

- to the specification and demonstration of RAMS for all railway applications and at all levels of such an application, as appropriate, from complete railway routes to major systems within a railway route, and to individual and combined sub-systems and components within these major systems, including those containing software; in particular:
- to new systems;
- to new systems integrated into existing systems in operation prior to the creation of this standard, although it is not generally applicable to other aspects of the existing system;
- to modifications of existing systems in operation prior to the creation of this standard, although it is not generally applicable to other aspects of the existing system.
- at all relevant phases of the lifecycle of an application;
- for use by Railway Authorities and the railway support industry.

NOTE Guidance on the applicability is given in the requirements of this standard.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references, the latest edition of the publication referred to applies.

EN ISO 9001	1994	<i>Quality systems — Model for quality assurance in design, development, production, installation and servicing</i>
EN ISO 9002	1994	<i>Quality systems — Model for quality assurance in production, installation and servicing</i>
EN ISO 9003	1994	<i>Quality systems — Model for quality assurance in final inspection and test</i>
EN 50128(*)		<i>Railway applications — Software for railway control and protection systems</i>
ENV 50129	1998	<i>Railway applications — Safety related electronic systems for signalling</i>
IEC 60050(191)	1990	<i>International Electrotechnical Vocabulary — Chapter 191: Dependability and quality of service</i>
IEC 61508	series	<i>Functional safety of electrical/electronic/programmable electronic safety-related Systems</i>

(*) In preparation

3 Definitions

For the purposes of this standard, the following definitions apply.

3.1

apportionment

a process whereby the RAMS elements for a system are sub-divided between the various items which comprise the system to provide individual targets

3.2

assessment

the undertaking of an investigation in order to arrive at a judgement, based on evidence, of the suitability of a product

3.3

audit

a systematic and independent examination to determine whether the procedures specific to the requirements of a product comply with the planned arrangements, are implemented effectively and are suitable to achieve the specified objectives

3.4

availability

the ability of a product to be in a state to perform a required function under given conditions at a given instant of time or over a given time interval assuming that the required external resources are provided

3.5

commissioning

a collective term for the activities undertaken to prepare a system or product prior to demonstrating that it meets its specified requirements

3.6

common cause failure

a failure which is the result of an event(s) which causes a coincidence of failure states of two or more components leading to a system failing to perform its required function

3.7

compliance

a demonstration that a characteristic or property of a product satisfies the stated requirements

3.8

configuration management

a discipline applying technical and administrative direction and surveillance to identify and document the functional and physical characteristics of a configuration item, control change to those characteristics, record and report change processing and implementation status and verify compliance with specified requirements

3.9

corrective maintenance

the maintenance carried out after fault recognition and intended to put a product into a state in which it can perform a required function

3.10

dependent failure

the failure of a set of events, the probability of which cannot be expressed as the simple product of the unconditional probabilities of the individual events

3.11

down time

the time interval during which a product is in a down state. (IEC 60050(191))

3.12

failure cause

the circumstances during design, manufacture or use which have led to a failure. (IEC 60050(191))

3.13

failure mode

the predicted or observed results of a failure cause on a stated item in relation to the operating conditions at the time of the failure

3.14

failure rate

the limit, if this exists, of the ratio of the conditional probability that the instant of time, T , of a failure of a product falls within a given time interval $(t, t+\Delta t)$ and the length of this interval, Δt , when Δt tends towards zero, given that the item is in an up state at the start of the time interval

3.15

fault mode

one of the possible states of a faulty product for a given required function. (IEC 60050(191))

3.16

fault tree analysis

an analysis to determine which fault modes of the product, sub-products or external events, or combinations thereof, may result in a stated fault mode of the product, presented in the form of a fault tree

3.17

hazard

a physical situation with a potential for human injury

3.18

hazard log

the document in which all safety management activities, hazards identified, decisions made and solutions adopted are recorded or referenced. Also known as a "Safety Log". (ENV 50129)

3.19

logistic support

the overall resources which are arranged and organized in order to operate and maintain the system at the specified availability level at the required lifecycle cost

3.20

maintainability

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))

3.21

maintenance

the combination of all technical and administrative actions, including supervision actions, intended to retain a product in, or restore it to, a state in which it can perform a required function. (IEC 60050(191))

3.22

maintenance policy

a description of the inter-relationship between the maintenance echelons, the indenture levels and the levels of maintenance to be applied for the maintenance of an item. (IEC 60050(191))

3.23

mission

an objective description of the fundamental task performed by a system

3.24

mission profile

outline of the expected range and variation in the mission with respect to parameters such as time, loading, speed, distance, stops, tunnels, etc., in the operational phases of the lifecycle

3.25

preventive maintenance

the maintenance carried out at pre-determined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item. (IEC 60050(191))

3.26

railway authority

the body with the overall accountability to a Regulator for operating a railway system

NOTE Railway authority accountabilities for the overall system or its parts and lifecycle activities are sometimes split between one or more bodies or entities. For example:

- the owner(s) of one or more parts of the system assets and their purchasing agents;
- the operator of the system;
- the maintainer(s) of one or more parts of the system;
- etc.

Such splits are based on either statutory instruments or contractual agreements. Such responsibilities should therefore be clearly stated at the earliest stages of a system lifecycle.

3.27

railway support industry

generic term denoting supplier(s) of complete railway systems, their sub-systems or component parts

3.28

RAM programme

a documented set of time scheduled activities, resources and events serving to implement the organizational structure, responsibilities, procedures, activities, capabilities and resources that together ensure that an item will satisfy given RAM requirements relevant to a given contract or project. (IEC 60050(191))

3.29

RAMS

an acronym meaning a combination of Reliability, Availability, Maintainability and Safety

3.30

reliability

the probability that an item can perform a required function under given conditions for a given time interval (t_1 , t_2). (IEC 60050(191))

3.31

reliability growth

a condition characterized by a progressive improvement of a reliability performance measure of an item with time. (IEC 60050(191))

3.32

repair

that part of a corrective maintenance in which manual actions are performed on a item. (IEC 60050(191))

3.33**restoration**

that event when an item regains the ability to perform a required function after a fault. (IEC 60050(191))

3.34**risk**

the probable rate of occurrence of a hazard causing harm and the degree of severity of the harm

3.35**safety**

freedom from unacceptable risk of harm

3.36**safety case**

the documented demonstration that the product complies with the specified safety requirements

3.37**safety integrity**

the likelihood of a system satisfactorily performing the required safety functions under all the stated conditions within a stated period of time

3.38**safety integrity level (SIL):**

one of a number of defined discrete levels for specifying the safety integrity requirements of the safety functions to be allocated to the safety related systems. Safety Integrity Level with the highest figure has the highest level of safety integrity

3.39**safety plan**

a documented set of time scheduled activities, resources and events serving to implement the organizational structure, responsibilities, procedures, activities, capabilities and resources that together ensure that an item will satisfy given safety requirements relevant to a given contract or project

3.40**safety regulatory authority**

often a national government body responsible for setting or agreeing the safety requirements for a railway and ensuring that the railway complies with the requirements

3.41**system lifecycle**

the activities occurring during a period of time that starts when a system is conceived and end when the system is no longer available for use, is decommissioned and is disposed

3.42**systematic failures**

failures due to errors in any safety lifecycle activity, within any phase, which cause it to fail under some particular combination of inputs or under some particular environmental condition

3.43**tolerable risk**

the maximum level of risk of a product that is acceptable to the Railway Authority

3.44**validation**

confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use have been fulfilled

3.45

verification

confirmation by examination and provision of objective evidence that the specified requirements have been fulfilled

NOTE For clarification between verification and validation see Figure 11 and 5.2.9.

4 Railway RAMS

4.1 Introduction

4.1.1 Clause 4 of this standard provides baseline information on the subject of RAMS and RAMS engineering. The purpose of this clause is to provide the reader with sufficient background information to enable the effective application of this standard to railway systems.

4.1.2 Railway RAMS is a major contributor to the Quality of Service provided by a Railway Authority. Railway RAMS is defined by several contributory elements; consequently, this clause of this European Standard is structured as follows:

- 1) Subclause 4.2 examines the relationship between railway RAMS and quality of service.
- 2) Subclauses 4.3 to 4.8 examine aspects of railway RAMS, namely:
 - the elements of RAMS;
 - the factors which influence and means to achieve RAMS;
 - risk and safety integrity.

4.1.3 Where possible within this clause, internationally defined terms are used but where new terms are required or where recognized terms have been made specific in the railway context, these are defined in clause 3 of this standard.

4.1.4 Within this European Standard, the sequence "system, sub-system, component" is used to demonstrate the breakdown of any complete application into its constituent parts. The precise boundary of each term (system, sub-system and component) will depend upon the specific application.

4.1.5 A system can be defined as an assembly of sub-systems and components, connected together in an organized way, to achieve specified functionality. Functionality is assigned to sub-systems and components within a system and the behaviour and state of the system is changed if the sub-system or component functionality changes. A system responds to inputs to produce specified outputs, whilst interacting with an environment.

4.2 Railway RAMS and quality of service

4.1.2 This subclause introduces the link between RAMS and quality of service for an undertaking.

4.2.2 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 characterized 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. System RAMS, in the context of this European Standard, is a combination of reliability, availability, maintainability and safety, RAMS.

4.2.3 The goal of a railway system is to achieve a defined level of rail traffic in a given time, safely. Railway RAMS describes the confidence with which the system can guarantee the achievement of this goal. Railway RAMS has a clear influence on the quality with which the service is delivered to the customer. Quality of Service is influenced by other characteristics concerning functionality and performance, for example frequency of service, regularity of service and fare structure. This relationship is shown in Figure 1.

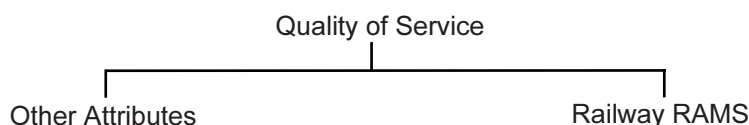


Figure 1 — Quality of Service and Railway RAMS

4.3 Elements of railway RAMS

- 4.3.1** This subclause introduces the interaction between RAMS elements, reliability, availability, maintainability and safety, in the context of railway systems.
- 4.3.2** Safety and availability are inter-linked in the sense that a weakness in either or mismanagement of conflicts between safety and availability requirements may prevent achievement of a dependable system. The inter-linking of railway RAMS elements, reliability, availability, maintainability and safety is shown in Figure 2.
- 4.3.3** Attainment of in-service safety and availability targets can only be achieved by meeting all reliability and maintainability requirements and controlling the ongoing, long-term, maintenance and operational activities and the system environment.
- 4.3.4** Security, as an element that characterizes the resilience of a railway system to vandalism and unreasonable human behaviour, can be considered as a further component of RAMS. However, consideration of security is outside the scope of this standard.

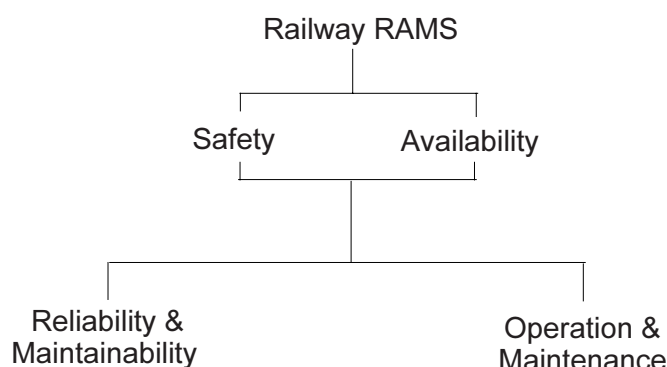


Figure 2 — Inter-relation of Railway RAMS elements

- 4.3.5** Technical concepts of availability are based on a knowledge of:

- a) reliability in terms of:
 - all possible system failure modes in the specified application and environment;
 - the probability of occurrence of each failure or alternatively, the rate of occurrence of each failure;
 - the effect of the failure on the functionality of the system.
- b) maintainability in terms of:
 - time for the performance of planned maintenance;
 - time for detection, identification and location of the faults;
 - time for the restoration of the failed system (unplanned maintenance).
- c) operation and maintenance in terms of:
 - all possible operation modes and required maintenance, over the system lifecycle;
 - the human factor issues.

4.3.6 Technical concepts of safety are based on a knowledge of:

- a) all possible hazards in the system, under all operation, maintenance and environment modes.
- b) the characteristic of each hazard in terms of its severity of consequences.
- c) safety/safety related failures in terms of:
 - All system failure modes that could lead to a hazard (safety related failure modes). This is a sub-set of all reliability failure modes (a));
 - The probability of occurrence of each safety related system failure mode;
 - Sequence and/or coincidence of events, failures, operational states, environment conditions, etc., in the application, that may result in an accident. (i.e. a hazard resulting in an accident);
 - The probability of occurrence of each of the events, failures, operational states, environment conditions, etc., in the application.
- d) maintainability of safety related parts of the system in terms of:
 - the ease of performing maintenance on those aspects or parts of the system or its components that are associated with a hazard or with a safety related failure mode;
 - probability of errors occurring during maintenance actions on those safety related parts of the system;
 - time for restoring the system into a safe state.
- e) system operation and maintenance of safety related parts of the system in terms of:
 - human factors influence on the effective maintenance of all safety related parts of the system and safe operation of the system;
 - Tools, facilities and procedures for effective maintenance of the safety related parts of the system and for safe operation;
 - effective controls and measures for dealing with a hazard and mitigating its consequences.

4.3.7 Failures in a system, operating within the bounds of an application and environment, will have some effect on the behaviour of the system. All failures adversely effect the system reliability whereas only some specific failures will have an adverse effect on safety within the particular application. Environment may also influence the functionality of the system and in turn the safety of the railway application. These links are shown in Figure 3.

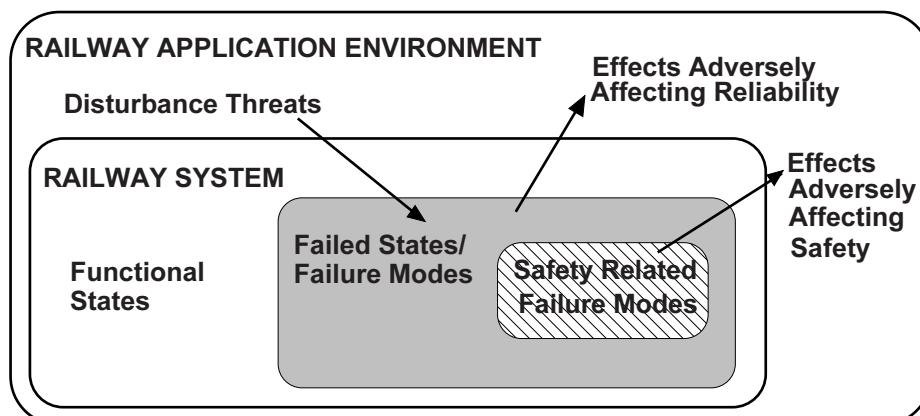


Figure 3 — Effects of Failures Within a System

- 4.3.8** A dependable railway system can only be realized through consideration of the interactions of RAMS elements within a system and the specification and achievement of the optimum RAMS combination for the system.

4.4 Factors influencing railway RAMS

4.4.1 General

- 4.4.1.1** This subclause introduces and defines a process to support the identification of factors which influence the RAMS of railway systems, with particular consideration given to the influence of human factors. These factors, and their effects, are an input to the specification of RAMS requirements for systems.

- 4.4.1.2** The RAMS of a railway system is influenced in three ways, by sources of failure introduced internally within the system at any phase of the system lifecycle (system conditions), by sources of failure imposed on the system during operation (operating conditions) and by sources of failure imposed on the system during maintenance activities (maintenance conditions). These sources of failure can interact. This relationship is shown in Figure 4 and detailed in Figure 5.

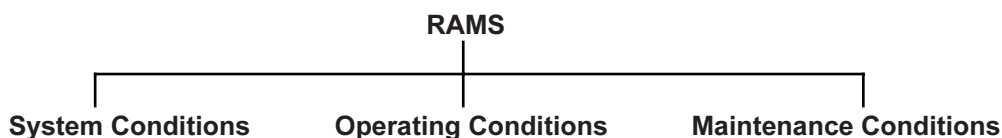


Figure 4 — Influences on RAMS

- 4.4.1.3** To realize dependable systems, factors which could influence the RAMS of the system need to be identified, their effect assessed and the cause of these effects managed throughout the lifecycle of the system, by the application of appropriate controls, to optimize system performance.

4.4.2 Categories of factors

- 4.4.2.1** This subclause details a process for the definition of those factors which will affect the successful achievement of a system which complies with specified RAMS requirements.

- 4.4.2.2** At a high level, the factors which influence system RAMS are generic, applying across all industrial applications. Figure 5 includes some generic factors which influence transport system RAMS. This figure also shows the interaction between these factors. To identify detailed factors which influence the RAMS of railway systems, each generic influencing factor shall be considered in the context of the specific system.

- 4.4.2.3** An analysis of human factors, with respect to their effect on system RAMS, is inherent within the “systems approach” required by this standard.

- 4.4.2.4** Human factors can be defined as the impact of human characteristics, expectations and behaviour upon a system. These factors include the anatomical, physiological and psychological aspects of humans. The concepts within human factors are used to enable people to carry out work efficiently and effectively, with due regard for human needs on issues such as health, safety and job satisfaction.

- 4.4.2.5** Railway applications typically involve a wide range of human groups, from passengers, operational staff and staff responsible for implementing systems to others affected by the railway operation, such as car drivers at level crossings. Each is capable of reacting to situations in different ways. Clearly, the potential impact of humans on the RAMS of a railway system is great. Consequently, the achievement of railway RAMS requires more rigorous control of human factors, throughout the entire system lifecycle, than is required in many other industrial applications.
- 4.4.2.6** Humans shall be considered as possessing the ability to positively contribute to the RAMS of a railway system. To achieve this aim, the manner in which human factors can influence railway RAMS should be identified and managed throughout the entire lifecycle. This analysis should include the potential impact of human factors on railway RAMS within the design and development phases of the system.
- 4.4.2.7** Whilst the need to address human factors within the lifecycle is generic, the precise influence of human factors on RAMS is specific to the application under consideration.
- 4.4.2.8** Generic factors, including those contained in Figure 5, should be reviewed in the context of the railway system under consideration. The Railway Authority shall specify any non-applicable factors in their call for tenders. Each applicable generic factor shall be assessed and detailed influencing factors, specific to the application, systematically derived. Human factors issues, a core aspect within an integrated RAMS management process, shall be addressed within this assessment.
- 4.4.2.9** The process of deriving detailed influencing factors shall be supported by the use of the two checklists covering railway specific factors (4.4.2.10) and human factors (4.4.2.11), or as an alternative presentation, Figure 5.

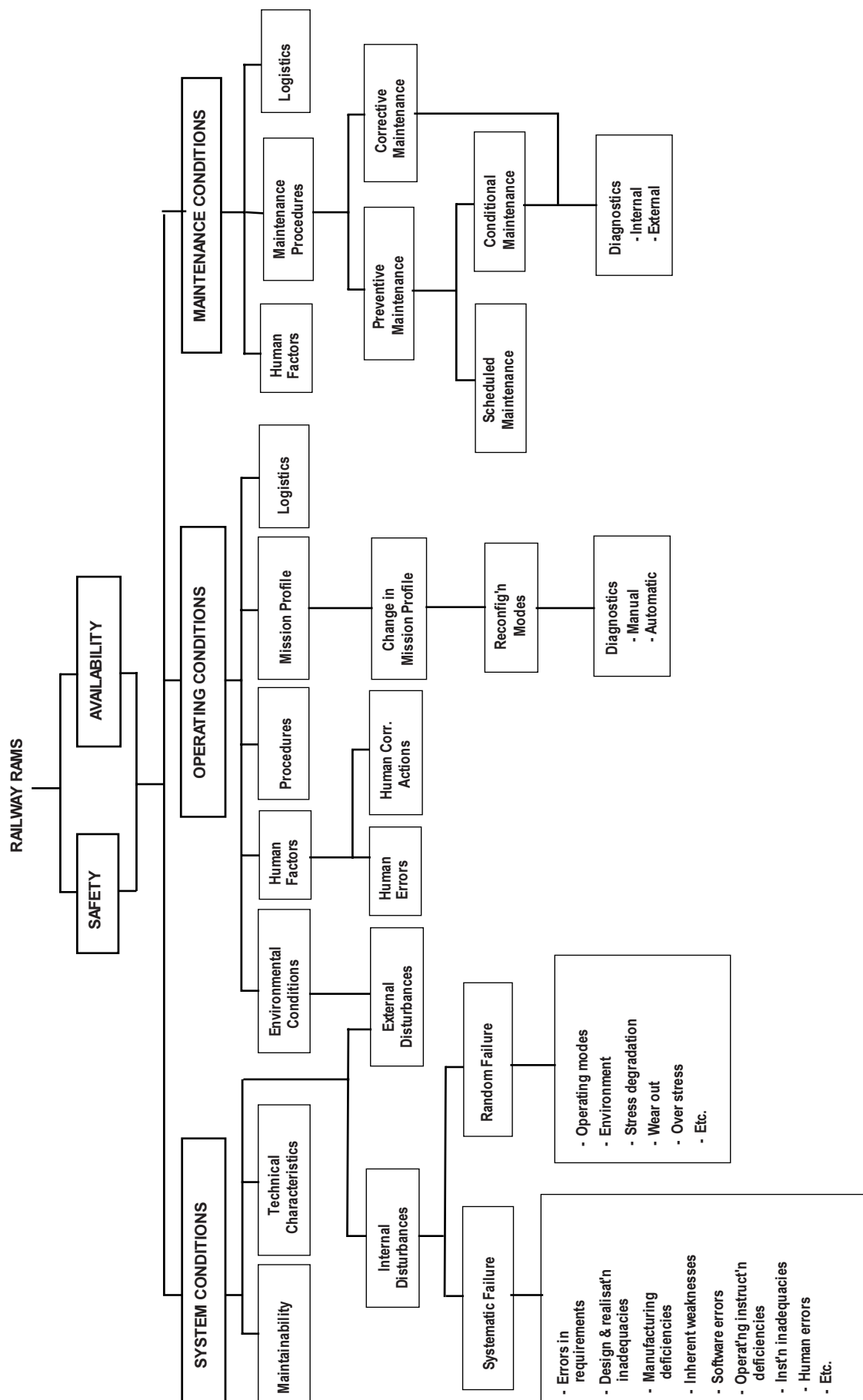


Figure 5 — Factors Influencing Railway RAMS

4.4.2.10 The derivation of detailed railway specific influencing factors should include, but not be limited to, a consideration of each of the following railway specific factors. It should be noted that the following checklist is non-exhaustive and should be adapted to the scope and purpose of the application:

- a) system operation:
 - the tasks which the system has to perform and the conditions in which the tasks have to be performed;
 - the co-existence of passengers, freight, staff and systems within the operating environment;
 - system life requirements, including system life expectancy, service intensity and lifecycle cost requirements.
- b) environment:
 - the physical environment;
 - the high level of integration of railway systems within the environment;
 - the limited opportunity for testing complete systems in the railway environment.
- c) application conditions:
 - the constraints imposed by existing infrastructure and systems on the new system;
 - the need to maintain rail services during lifecycle tasks.
- d) operating conditions:
 - trackside-based installation conditions;
 - trackside-based maintenance conditions;
 - the integration of existing systems and new systems during commissioning and operation.
- e) failure categories:
 - the effects of failure within a distributed railway system.

4.4.2.11 The derivation of detailed human influencing factors should include, but not be limited to, a consideration of each of the following human factors. It should be noted that the following checklist is non-exhaustive and should be adapted to the scope and purpose of the application.

- a) the allocation of system functions between human and machine.
- b) the effect on human performance within the system of:
 - the human/system interface;
 - the environment, including the physical environment and ergonomic requirements;
 - human working patterns;
 - human competence;
 - the design of human tasks;
 - human interworking;
 - human feedback process;
 - railway organizational structure;
 - railway culture;
 - professional railway vocabulary;
 - problems arising from the introduction of new technology.
- c) requirements on the system arising from:
 - human competence;
 - human motivation and aspiration support;
 - mitigating the effects of human behavioural changes;
 - operational safeguards;
 - human reaction time and space.

- d) the requirements on the system arising from human information processing capabilities, including:
 - human/machine communications;
 - density of information transfer;
 - rate of information transfer;
 - the quality of information;
 - human reaction to abnormal situations;
 - human training;
 - supporting human decision making processes;
 - other factors contributing to human strain.
- e) the effect on the system of human/system interface factors, including:
 - the design and operation of the human/system interface;
 - the effect of human error;
 - the effect of deliberate human rule violation;
 - human involvement and intervention in the system;
 - human system monitoring and override;
 - human perception of risk;
 - human involvement in critical areas of the system;
 - human ability to anticipate system problems.
- f) human factors in system design and development, including:
 - human competency;
 - human independence during design;
 - human involvement in verification and validation;
 - interface between human and automated tools;
 - systematic failure prevention processes.

4.4.2.12 A diagrammatic approach to the derivation of detailed factors, such as the use of cause/effect diagrams, is recommended. An example of a much simplified cause/effect diagram is shown in Figure 6.

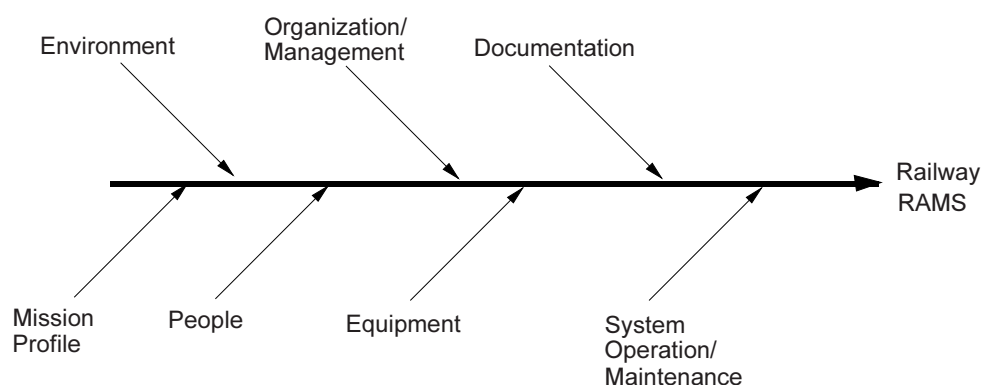


Figure 6 — Example of a Cause/Effect Diagram

4.4.3 Management of factors

The potential effect of each influencing factor on the RAMS of the railway system under consideration shall be evaluated at a level appropriate to the railway system under consideration. This evaluation shall include a consideration of the effect of each factor at each phase of the lifecycle and shall be at a level which is appropriate to the system under consideration. The evaluation shall address the interaction of associated influencing factors. For human factors, the evaluation shall also consider the effect of each factor in relation to each

4.5 The means to achieve railway RAMS requirements

4.5.1 General

4.5.1.1 The means to achieve railway RAMS requirements relates to controlling the factors which influence RAMS throughout the life of the system. Effective control requires the establishment of mechanisms and procedures to defend against sources of error being introduced during the realization and support of the system. Such defences need to take account of both random and systematic failures.

4.5.1.2 The means used to achieve RAMS requirements are based on the concept of taking precautions to minimize the possibility of an impairment occurring as a result of an error during the lifecycle phases. Precaution is a combination of:

- a) prevention: concerned with lowering the probability of the impairment.
- b) protection: concerned with lowering the severity of the consequences of the impairment;

4.5.1.3 The strategy to achieve RAMS requirements for the system, including the use of prevention and/or protection means, shall be justified.

4.5.2 RAMS specification

4.5.2.1 The specification of RAMS requirements is a complex process. Annex A of this standard provides an example outline of a RAMS requirements specification, based on the process detailed in this document. Annex B of this standard provides an example outline procedure for the definition of a RAMS programme, based on the requirements of this standard. Both informative annexes are for guidance only and have been populated using rolling stock as an example.

A list of suitable tools for RAMS analysis is also included in annex B. Selection of an appropriate tool will depend on the system under consideration and on factors such as the criticality, novelty, complexity, etc. of the system.

4.5.2.2 Table 1 defines RAM failure categories suitable for use in railway applications.

Table 1 — RAM Failure Categories

Failure Category	Definition
Significant (Immobilizing 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 system 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 a system achieving its specified performance and - does not meet criteria for Significant or Major failures

4.5.2.3 Suitable parameters to characterize reliability, availability, maintainability, logistic support and safety requirements of railway systems are shown in annex C (informative). Specific parameters will depend on the system under consideration. All RAMS parameters used should be agreed between the Railway Authority and the Railway Support Industry. Where parameters may be expressed in alternative dimensions, conversion factors should be provided.

4.6 Risk

4.6.1 Risk concept

The concept of risk is the combination of two elements:

- the probability of occurrence of an event or combination of events leading to a hazard, or the frequency of such occurrences;
- the consequence of the hazard.

4.6.2 Risk analysis

4.6.2.1 Risk analysis shall be performed at various phases of the system life cycle by the authority responsible for that phase and shall be documented. The documentation shall contain, as a minimum:

- a) analysis methodology;
- b) assumptions, limitations and justification of the methodology;
- c) hazard identification results;
- d) risk estimation results and their confidence levels;
- e) results of trade-off studies;
- f) data, their sources and confidence levels;
- g) references.

4.6.2.2 Table 2 provides, in qualitative terms, typical categories of probability or frequency of occurrence of a hazardous event and a description of each category for a railway system. The categories, their numbers, and their numerical scaling to be applied shall be defined by the Railway Authority, appropriate to the application under consideration.

Table 2 — Frequency of occurrence of hazardous events

Category	Description
Frequent	Likely to occur frequently. The hazard will be continually experienced
Probable	Will occur several times. The hazard can be expected to occur often
Occasional	Likely to occur several times. The hazard can be expected to occur several times
Remote	Likely to occur sometime in the system life cycle. The hazard can reasonably expected to occur
Improbable	Unlikely to occur but possible. It can be assumed that the hazard may exceptionally occur.
Incredible	Extremely unlikely to occur. It can be assumed that the hazard may not occur.

4.6.2.3 Consequence analysis shall be used to estimate the likely impact. Table 3 describes typical hazard severity levels and the consequences associated with each severity level for all railway systems. The number of severity levels and the consequences for each severity level to be applied shall be defined by the Railway Authority, appropriate for the application under consideration.