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Data entry – draft starts next page

Standard number	AS 7718
Version year	2025
Standard name	Signalling Design Process Management
Standing Committee	Train Control Systems
Development group member organisations	Metro Trains Melbourne; Wabtec; TfNSW; Queensland Rail; Frauscher Sensor Technology India; Hayes Railway Signalling Pty Ltd; JMDR; Department of Transport and Planning
Review type	This Standard was issued for public consultation and was independently validated before being approved.
First published	AS 7718:2017
ISBN	TBD
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Development draft history

Draft version	Draft date	Notes
8	21/10/2025	Updated based on Draft 7 review comments
7	21/10/2025	Updated based on Draft 5 and 6 review comments
6	17/10/2025	New content for DG consideration.
5	17/9/2025	New structure for DG consideration.
4	15/9/2025	Updated based on Draft 3 review comments
3	29/07/2025	New structure for DG consideration.
2	10/6/2025	Updated based on Draft 1 review comments
1	24/04/2025	Updated for initial DG review.
0	22/04/2025	Initial version generated from the most recently published version.

Preface

This document was prepared by the Signalling Design Process Management Development Group, overseen by the RISSB Train Control Systems Standing Committee.

This document has been significantly altered from the previous version, including:

(a) more clearly defined process steps;

(b) information on documentation types and purposes; and

(c) clarity of roles and responsibilities within the process.

Objective

The objective of this document is to provide the Australian rail industry with a set of mandatory and recommended requirements for the signalling design management process. The main purpose is to promote a consistent approach to the signalling design process across the Australian rail industry.

This comprehensive process, if well implemented will substantially reduce the issues when developing the design as all aspects are considered in this process which will lead to:

(a) shortening of the implementation period;

(b) reduce the need for redesign;

(c) enable transferability of people;

(d) having a standard process;

(e) reduction in errors; and

(f) potential reduction in costs.

Compliance

There are four types of provisions contained within Australian Standards developed by RISSB:

(a) Requirements.

(b) Recommendations.

(c) Permissions.

(d) Constraints.

Requirements – it is mandatory to follow all requirements to claim full compliance with the Standard. Requirements are identified within the text by the term ‘shall’.

Recommendations – do not mention or exclude other possibilities but do offer the one that is preferred. Recommendations are identified within the text by the term ‘should’.

Recommendations recognize that there could be limitations to the universal application of the control, i.e. the identified control is not able to be applied or other controls are more appropriate or better.

For compliance purposes, where a recommended control is not applied as written in the standard it could be incumbent on the adopter of the standard to demonstrate their actual method of controlling the risk as part of their WHS or Rail Safety National Law obligations. Similarly, it could also be incumbent on an adopter of the standard to demonstrate their method of controlling the risk to contracting entities or interfacing organisations where the risk may be shared.

Permissions – conveys consent by providing an allowable option. Permissions are identified within the text by the term ‘may’.

Constraints – provided by an external source such as legislation. Constraints are identified within the text by the term ‘must’.

RISSB Standards address known hazards within the railway industry. Hazards, and clauses within this Standard that address those hazards, are listed in Appendix A.

Appendices in RISSB Standards may be designated either “normative” or “informative”. A "normative" appendix is an integral part of a Standard and compliance with it is a requirement, whereas an "informative" appendix is only for information and guidance.

Commentary

Commentary *C Preface*

This Standard includes a commentary on some of the clauses. The commentary directly follows the relevant clause, is designated by ‘C’ preceding the clause number and is printed in italics in a box. The commentary is for information and guidance and does not form part of the Standard.

Table of Contents

Figures

Section 1 Scope and general

1.1 Scope

This document specifies the process for the production and management of signalling designs for use on rail networks.

This document demonstrates how the signalling design process aligns with ISO 15288 and IEC 62278 (EN 50126) and is applicable to all signalling design works.

The processes described in this document can be scaled depending on the scope and size of the signalling project.

NOTE:

The following standards are interchangeable:

IEC 62278 and EN 50126-1

IEC 62279 and EN 50128

IEC 62425 and EN 50129

This document is intended to be used by project managers, signalling designers and suppliers of railway systems to assist in the implementation of a detailed signalling design process.

This document covers signalling design management through the design, installation & construction and testing & commissioning stages.

This document does not cover signalling system installation, construction, testing, commissioning, or operations and maintenance.

NOTE:

Implementation of new or bespoke signalling application and equipment could require a greater level of rigour than provided in this document.

1.2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document:

- AS 7702, *Rail Equipment Type Approval*
- AS 7770, *Rail Cyber Security*
- AS 7739.1, *Digital Engineering for Fixed Rail Infrastructure Part 1, Principles and Concepts*
- IEC 62278, *Railway Applications - The specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS)*
- IEC 62279, *Railway Applications - Communication, Signalling and Processing Systems - Software for Railway Control and Protection Systems*
- IEC 62425, *Railway Applications Communication, Signalling and Processing Systems - Safety Related Electronic Systems for Signalling*
- IEC 62443 (Series), *Security for Industrial Automation and Control Systems*
- ISO 10007, *Quality management – Guidelines for configuration management*

NOTE:

Documents for informative purposes are listed in a Bibliography at the back of the Standard.

1.3 Defined terms and abbreviations

For the purposes of this document, the following terms and definitions apply:

1.3.1
as built
as in service

design that accurately reflects the signaling system as installed and commissioned

1.3.2
derogation
waiver

process which captures non-conformity to requirements

1.3.3
drawings
site specific or standard documented layouts, plans, diagrams, tables, schematics, final arrangements and the like that set out the design and/or configuration of signalling infrastructure assets (e.g. physical dimensions and compositions, temporal and/or spatial arrangements, physical and/or logical interconnections) either existing, pre-existing, or proposed

1.3.4
design modification
minor change to the design after approval to use, often to rectify errors

1.3.5
design change
significant alteration to the design due to scope change or other major change

1.3.6
RAMS
reliability, availability, maintainability and safety

1.3.7
RIM
rail infrastructure manager as defined in Rail Safety National Law

1.3.8
RTO
rail transport operator as defined in Rail Safety National Law

1.3.9
SFAIRP
so far as is reasonably practicable

1.3.10
verification
confirmation, through the provision of objective evidence, that specified requirements have been fulfilled

Note 1 to entry: The term verified is used to designate the corresponding status.

Note 2 to entry: Design verification is the application of tests and appraisals to assess conformity of a design to the specified requirement.

Note 3 to entry: Verification is conducted at various life cycle phases of development, examining the system and its constituents to determine conformity to the requirements specified at the beginning of that life cycle phase.

[SOURCE: EN 50126-1:2017]

General rail industry terms and definitions are maintained in the RISSB Glossary. Refer to: https://www.rissb.com.au/glossary/

Section 2 Signalling design process overview

2.1 General

The purpose of a signalling system design process is to demonstrate that the signalling design:

(a) mitigates:

(i) safety hazards SFAIRP;

(ii) reliability, availability and maintainability issues;

(iii) physical and cyber security hazards; and

(iv) human factors integration issues.

(b) achieves the scope of the project;

(c) has managed all design changes appropriately;

(d) has correct application of version control; and

(e) has been produced by appropriately qualified, trained and competent personnel.

Designs shall be in accordance with the identified and approved standards and procedures. Alternatively, for novel designs that are not covered by existing standards, the design should be developed in accordance with the requirements of EN 50126, EN 50128 and EN 50129 as applicable.

Cybersecurity requirements are provided in IEC 62443 and AS 7770

Application of digital engineering technologies should be in accordance with AS 7739.1

2.2 System engineering lifecycle and signalling design

The systems engineering V-cycle described in ISO 15288 can be overlaid with the RAMS process described in IEC 62278 (EN 50126) as shown in figure 1.

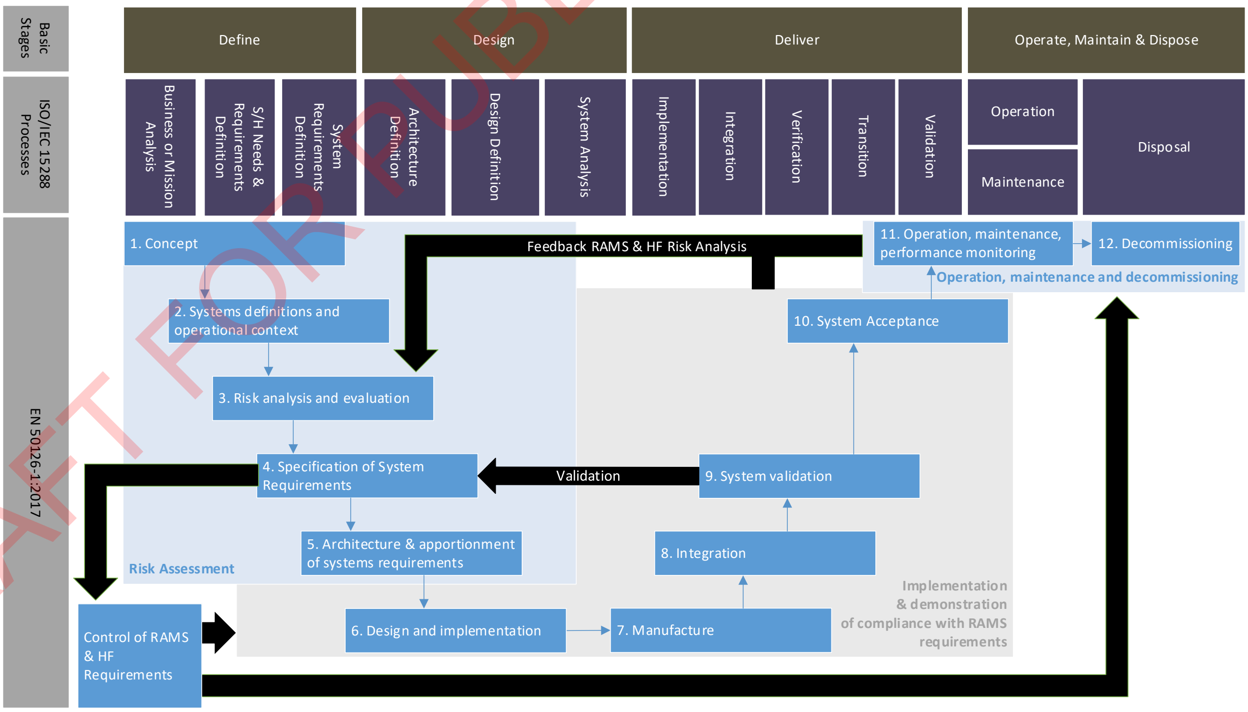

Figure 1 Approximate alignment of ISO 15288 processes and IEC 62278 phases

Source: RISSB Reliability, Availability, and Maintainability (RAM) Guideline

Figure 2 provides a high-level overview of the alignment between the stages laid out in this document and IEC 62278.

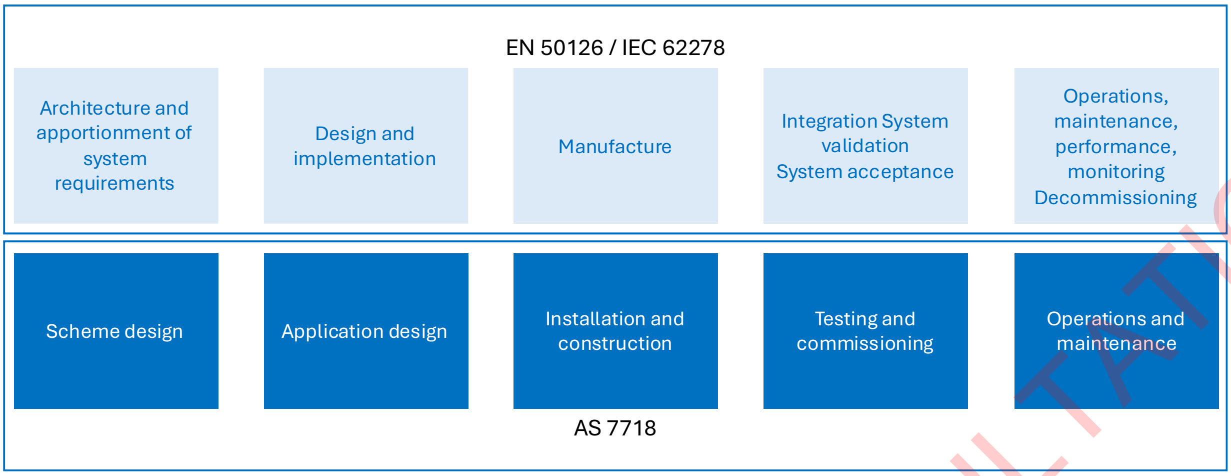

Figure 2 Alignment between IEC 62278 phases and the signalling design process

Stages shown in IEC 62278 not described in the above diagram are not covered in this document.

2.3 Inputs into signalling design

For the purposes of this document the following assumptions are made:

> NOTE:
>
> This information is developed in the define stage – see figure 1.

(a) The following information has been developed and approved:

(i) Business case and project scope – see Appendix D for risks associated with acceptance of business case and project scope.

(ii) Operational concept definition.

> NOTE:
>
> The operational concept definition describes what the signalling system needs to provide in terms of operational requirements, such as number of trains per hour or length of trains.

(iii) Maintenance concept definition.

> NOTE:
>
> The maintenance concept definition describes the maintenance requirements of the signalling system. This could include access, MTBF, etc.

(iv) Technical requirements (system level).

> NOTE:
>
> Technical requirements include the type of signalling equipment to be used, the required interfaces with other systems such as rolling stock, traction power, etc.

(v) Scope of works for associated disciplines.

> NOTE:
>
> Scope of works for associated disciplines includes track (location of track, points, etc.), civil (earthworks, building location, etc.) and electrical infrastructure (power supplies, earthing requirements, etc)

(vi) Concept of delivery.

> NOTE:
>
> Concept of delivery includes any staging of the project and the proposed testing and commissioning strategy.

(vii) Concept architecture.

(viii) Type approval applications.

(ix) Operational, system, user and interface requirements specifications (see appendix C).

(x) System and sub-system requirements specification.

> NOTE:
>
> The system and sub-system requirements specification typically covers multiple disciplines (including infrastructure, traction power, etc.) so would not be part of the signalling design process.

(xi) Specification of an appropriate level of safety.

(xii) Drawings, plans, surveys, etc. for existing signalling systems and associated infrastructure are available.

> NOTE:
>
> For correlation of drawings, plans, surveys, etc. for existing signalling systems, see clause 2.6

(b) The required standards have been developed and approved, or identified from an existing suite of standards, and are available for use.

(c) All business case options have been assessed and a preferred design option agreed (see section 2.4).

(d) Stakeholders have been identified, including representatives from relevant disciplines (infrastructure, operations, etc.).

> NOTE:
>
> Stakeholders are those who are affected by the signalling component of the project. This can include operational and maintenance personnel, as well as designers from other disciplines.

2.4 Design options

Differing design solutions should be created, modelling them to a level of detail that permits comparison against the specifications expressed in the system requirements, performance, costs, time scales and risks expressed in the stakeholder requirements. This should include:

(a) assessing and communicating the emergence of adverse system properties resulting from the interaction of candidate system elements or from changes in a system element;

(b) ensuring that the constraints of enabling systems are assessed as part of the design; and

(c) performing effectiveness assessments, trade-off analyses and risk analyses that lead toward realizing a feasible, effective, stable and optimized design.

The delivery strategy, developed as part of the design options, shall assess the requirements associated with implementation, interface and access constraints.

The final option shall be confirmed prior to commencing the scheme design phase.

2.5 Roles and responsibilities

The signalling design process involves many different roles and responsibilities. All personnel undertaking and/or supporting the tasks for the signalling design shall meet the competency requirements of the RIM.

Where the RIM does not have a specific requirement for competency for a design task, the personnel shall be able to demonstrate that they have the competency to undertake the task.

Where there are legislative requirements for accreditation for engineering work or other tasks, then these shall be addressed in the design management plan and personnel meeting the requirements allocated accordingly.

Records of the competence of personnel undertaking design tasks shall form part of the design management plan.

Further information on roles and responsibilities is provided in Appendix B.

> Commentary *C2.5*
>
> The Australasian Railway Association has developed the National Rail Matrices to assist rail transport operators in defining roles and the competencies required to carry out those roles, including for signalling design. Further information can be obtained at www.riw.net.au

2.6 Type approved equipment

The use of non-type approved equipment can have a significant impact to a project including:

(a) additional resourcing;

(b) training of signalling designer, tester, maintenance and operational staff;

(c) impact to program if designing at risk,

(d) impact on procurement due to risk;

(e) additional testing time;

(f) difficulty posed to integration; and

(g) additional acceptance requirements from the RTO.

Where possible, components used to make up the system to provide the required functionality and constraints apportioned from the system requirements specification (SRS), should be selected from those already type approved for that function by the RIM.

If there are no suitable type approved products, the selection of the equipment shall consider whether the product/system will achieve the defined acceptance criteria for the function(s) it will provide. Equipment not type approved shall be approved for use prior to inclusion into the design.

Type approval shall be in accordance with AS 7702.

2.7 Speciality engineering

Speciality engineering is integral to the signalling design process as it provides focus on certain characteristics or challenges of the system in which it is operating. This could include RAMS, security, human factors and environment specialists.

Speciality engineering looks at the functionality and interfaces of the specific application of the signalling system in terms of speciality engineering discipline, and identifies any related risks.

During the design and where applicable each speciality engineering discipline should interface in the following way:

(a) Assess the scope and requirements to determine speciality engineering tasks and input to the design process.

(b) Work with designers to identify speciality engineering risks related to the signalling design scope.

(c) Identify speciality engineering requirements to control the risks to be addressed by the design.

(d) Verify that the design controls the risk.

2.8 Correlation with existing designs

The integrity of the as-built records should be assessed where there is an identified risk of variations between the as-built drawings and the signalling equipment as installed. Where the signalling equipment has recently been correlated or installed, it may not be necessary to conduct a correlation.

Correlation should be conducted whenever confirmation is required that the artifacts used for signalling design accurately reflect the operational equipment.

Correlation should initially be undertaken through a review of the as-built records and the current signalling artifacts (known as a desktop review). Where a discrepancy is identified, a correlation plan should be developed. The correlation plan should clearly identify what requires correlation, as not all the equipment within a particular location could require correlation.

As the signalling design progresses, it may be necessary to conduct additional correlation activities.

2.9 Signalling design configuration and change management

2.9.1 Description

The purpose of signalling design configuration and change management is to:

(a) safely manage, control and document a process for design changes and design modifications at any point in the life cycle; and

(b) assure that at all points throughout the lifecycle of the signalling design, the current version is known and available for use as required by those in following stages of the signalling design.

Documentation of design changes cover the impact on the design outcomes of the project.

Documentation of design modifications cover error rectification and minor changes.

Documents developed in the signalling design process shall be recorded and managed. The management process defined in ISO 10007 should be followed.

The sharing (for review and acceptance) of signalling documentation shall be tracked and controlled.

2.9.2 Requirements

There shall be an approved process within the DMP for assessment and management of design changes and design modifications to ensure:

(a) the lifecycle of the change and the complexities associated with making that change in the current stage are assessed and appropriate controls defined;

(b) unique identification of changes to design drawings or documents;

(c) full traceability of each change;

(d) tracking of changes that affect interfaces;

(e) identification of impacts to affected interfaces and associated systems; and

(f) identification of changes to signalling design artifacts.

A configuration management system shall be in place that provides traceability between all configuration items so that when a change is approved for implementation, all affected configuration items can be identified and updated.

2.9.3 Guidance

2.9.3.1 Multiple users

Where signalling artifacts are being revised by multiple users concurrently the coordination of those designs and associated risk shall be managed.

The process for managing concurrent design works should be recorded in an overlapping design agreement or similar document. The process should document how the primary control party will provide the secondary party updates of the designs or commissioned update.

2.9.3.2 Design modifications

Design modifications are typically requested due to errors found during the installation or test and commissioning phase of the project. Changes made prior to the artifact being approved for construction (AFC) are not considered design modifications.

Design modifications should only be used for minor changes that do not affect the scope or requirements specifications for the project.

Design modifications to the approved designs shall be recorded in a design modification register.

Design modifications shall be identified using a unique allocation of identifier without increasing the revision number of the design.

The design modification register shall include:

(a) the artifact changed;
(b) the modification made;
(c) the reason for the modification (reference to installation or test log number);
(d) date of the change;
(e) reference to design resource allocation;
(f) unique identifier; and
(g) any other information that assists in the traceability of the design modification.

2.9.3.3 Design changes

Design changes are those which result in significant changes to a design, multiple design artifacts, other interfaces or disciplines. These are typically caused by changes to project scope and/or requirements specifications.

The signalling design shall be reviewed when there is any change to the project scope or requirement specification documentation. Changes may be required to previously approved design input documentation.

Design changes shall be controlled through the DMP. The version update panel for each design artifact shall be updated for each design change.

The reasons for each change shall be recorded in the DMP with corresponding project management inputs.

A log of changes or variations to the project shall be appended to the system requirement specification documentation.

2.10 Stageworks

The requirements for stage works shall be defined in the concept of delivery (See clause 2.3).

Where the signalling system is proposed to be delivered in several stages, the requirements for application design artifacts should be equally applied to the staged artifacts.

The introduction of various stages could introduce more cross boundary or interfaces that need to be specifically assessed for any new risks that they could introduce. This should equally include temporary operational or maintenance constraints that could result from the staged works.

The commissioning stages (if any) shall be clearly documented and communicated to all stakeholders as part of the signalling functional specification.

2.11 Review of design artifacts

2.11.1 Description

Review of design artifacts happen at various stages of the signalling design process, and to varying levels of detail.

Reviews provide a progressive assurance throughout the signalling design lifecycle. This can be summarized as:

(a) production check;

(b) independent verification;

(c) stakeholder review; and

(d) third-party review.

The requirements for each review type are detailed in clause 10.3

Each type of review should be done independently of each other (not done together and/or at the same time) and not re-prosecute what has already been done.

The types and requirements for review will vary depending on the complexity of the signalling design. For example, a design that mirrors a previously approved design could require only a production check and an independent review as the risk of error or non-conformance with defined standards could be low. However, a large signalling project or one which introduces new technologies could require all the above reviews to be conducted more than once due to the level of risk in the design.

The coordination, management and timing of reviews should be captured in the DMP.

2.11.2 Rationale

It is important that all design artifacts are reviewed:

(a) to progressively build confidence in the design;

> Commentary *C2.11.2-1*
>
> It is important that users of the design artifacts have confidence that the previous work has been completed to a high standard.

(b) for compliance with agreed standards, procedures and safety in design principles;

> Commentary *C2.11.2-2*
>
> Compliance provides confidence that the design follows good industry practice in management of associated risks.

(c) for alignment with requirements specifications;

Commentary *C.2.11.2-3*

Alignment provides confidence that the design is fit for purpose and meets stakeholders needs.

(d) to identify any risk that the design could introduce;

Commentary *C2.11.2-4*

Early identification of risk enables design modifications with minimal rework and project impact.

(e) to ensure that all necessary corrections have been incorporated; and

Commentary *C2.11.2-5*

It is important that all identified errors are addressed and rectified in the design.

(f) to reduce rework.

Commentary *C2.11.2-6*

Rework can have significant impact on project costs and timeframes. Early identification of errors or required changes reduce rework at later stages of the project.

2.11.3 Requirements

2.11.3.1 Production Check

A production check allows personal reflection and ensures that design intent is met, is operational and is safe. This ensures that all the correct inputs and outputs have been produced.

Commentary *C2.11.3.1*

A good consideration for the person who is conducting the check is 'Would I be confident to approve this design?'

A production check involves a detailed examination of the artifact for:

(a) accuracy;

(b) alignment with agreed inputs;

(c) compliance with agreed Standards;

(d) whether the design:

  (i) is functional; and

  (ii) meets RAMS principles.

(e) any applicable legislation; and

(f) alignment with:

  (i) the project scope and ORS;

  (ii) safety in design principles;

  (iii) Interface documents;

  (iv) associated drawings (e.g. signalling schematic when reviewing control tables); and

  (v) risk registers applicable to the project.

The production check shall be conducted by the person developing the design. A person working on an associated artifact may also conduct the production check (as a cross check). Where the artifact has been developed by a person under mentorship or training, the mentor/trainer should conduct the production check.

The production check is a detailed review, checking all aspects of the design.

2.11.3.2 Independent verification

Independent verification is a review conducted by a person independent of the design and who is able to objectively review the design without bias.

The independent verifier verifies the signalling design against the same requirements as the signalling designer and should be of equivalent or greater competence. This provides additional assurance that the correct inputs and outputs have been produced, the design is operational, safe and fully compliant with the agreed standards and processes.

An independent review involves a detailed examination of the same items as the production check (see clause 2.11.3.1).

A register of all identified issues shall be developed. The register shall include, as a minimum:

(a) date of review;

(b) reviewers name and position;

(c) unique number for each issue;

(d) document number or identifiable reference for the document;

(e) status of the issue;

(f) identified issue;

(g) reason for identification as an issue; and

(h) changes made to address the issue.

Where the issue is not resolved a reasoning shall be included.

2.11.3.3 Stakeholder review

Stakeholder subject matter experts should be given the opportunity to review and comment on the design artifacts. The level of review will depend on the artifact and the number of stakeholders affected by that component of the design.

Stakeholders can provide insights based on operational and maintenance experience that can assist in improving the signalling design.

Stakeholders are provided design artifacts to make sure the design:

(a) is fit for purpose;

(b) meets the agreed standards;

(c) aligns with the signalling functional specification; and

(d) doesn’t introduce new or additional risk.

Not all design artifacts are subject to stakeholder review. The DMP should specify which artifacts require stakeholder review.

Comments made to design artifacts shall be recorded for review by the signalling designer. A register of comments and actions against the comments may be developed for traceability. Where design changes are made, the independent verification review shall be done again.

Reviews may be conducted as workshops with interested stakeholders.

2.11.3.4 Third-party review

The third-party reviewer is a person, independent of the signalling designer and verifier, who may be engaged based on specific requirements of the design or the project. The third-party reviewer may be engaged where there is complexity added to the integration of the signalling subsystems either through various products suppliers or design tasks by multiple design contractors. A third-party reviewer may also be engaged where the integrity of the independent verification process has been compromised.

A third-party review can also be referred to as a system review.

The scope and requirements for a third-party review shall be clearly identified in the DMP.

The level and depth of review is based on the complexity of the design and the level of risk posed by the design. When conducting the third-party review, the following may be considered:

(a) Compatibility and alignment with other designs.

(b) Overall system functionality.

(c) Any applicable legislation.

(d) The project scope and ORS.

(e) Agreed standards, policies and procedures.

(f) Interface documents.

(g) Associated drawings (e.g. signalling schematic when reviewing control tables).

(h) Risk registers applicable to the project.

Section 3 Signalling design process

3.1 Process flow

Many documents start out as inputs to the design process. As the project progresses, these documents become further refined to become the final design documentation

Any changes to earlier design artifacts shall be assessed for their impact on other designs.

3.2 Scheme design

3.2.1 Description

This process builds a representation of a future signalling system that meets the defined requirements (see clause 3.2.3).

It is important that this information is developed and captured as the system (and sub-system) requirements definitions enable the delivery of the required operational and safety functions within the defined performance.

The scheme design phase creates a collection of artifacts that demonstrate and explain how the defined requirements will be met and provides the design requirements for the application design.

Where the signalling system is proposed to be delivered in several stages, the requirements for scheme design artifacts should be equally applied to the staged artifacts.

The scheme design results in design artifacts that feed into the application design.

Further information on these documents is provided in Appendix C.

3.2.2 Rationale

The documents developed in the scheme design stage form the basis of all detailed signalling design. Where these documents are undefined or poorly articulated, the signalling design can fail to meet the overarching intent of the signalling project, resulting in a signalling system that is not safe, fails to meet the requirements specifications, and/or requires significant rework.

3.2.3 Input artifacts

Information detailed in section 2.3 of this document should be finalized and approved to enable the development of the system requirements.

A critical input is the system requirements specification (see appendix C.3). Where this has not been developed, a signalling requirements specification (see appendix C.3) should be developed to input into the scheme design phase.

3.2.4 Requirement

The scheme design shall:

(a) develop a signalling requirements specification applicable to the signalling design;

(b) develop a design management plan in accordance with appendix C.6;

(c) demonstrate how the signalling design integrates into the wider railway network;

(d) demonstrate how the signalling design will meet the requirements agreed by the stakeholders;

(e) specify constraints that will affect the design of the signalling system and the means to realize those constraints;

(f) achieve the integrity and traceability of system requirements to the stakeholder requirements;

(g) define the criteria for acceptance of a requirement;

(h) describe how the scheme design will be deployed to meet the proposed scheme design; and

(i) mitigate:

(i) safety hazards SFAIRP;

(ii) reliability, availability and maintainability issues;

(iii) physical and cybersecurity hazards; and

(iv) human factors integration issues.

3.2.5 Outputs

A DMP and a signalling functional specification (SFS) shall be developed as part of the scheme design phase. These artifacts drive the scheme design and provide a reference for all phases of the signalling design process.

The following artifacts should also be developed once the SFS is developed:

(a) Signalling arrangement plan.

(b) Control tables.

(c) Aspect sequence charts.

(d) System architecture.

> NOTE:
>
> The determination of where the control tables task is assigned depends on the requirements of the project.

Further information on these documents is provided in appendix C.

These outputs should be subject to stakeholder reviews as described in section 2.11.3.3

3.3 Application design

3.3.1 Description

This stage should not commence until the artifacts described in section 3.2.5 have been developed and approved for use.

The purpose of the application design stage is to decompose the design artifacts described in section 2.3 and section 3.2.5 into a detailed hardware and software configuration that will provide the required functionality and performance of the signalling system for the specific application.

This stage shall result in an application design that is completely compliant with agreed signalling functional specification and signalling requirements, and that all requirements are verified as being traced from the previous stage.

Maintenance requirements should be provided for in the design as required to meet the specified maintainability and availability performance.

Designs should follow the agreed set of standards. On occasions where a design innovation is possible that does not comply with the agreed standards, a derogation or waiver may be required.

Completion of the application design shall result in the design used for installation of the signalling equipment or testing and commissioning (in the case of control tables, data, etc.).

This stage is used to develop the specific artifacts, in alignment with the SFS, required for the implementation of the signalling design to ensure:

(a) detailed designs are developed based on scheme design inputs;

(b) specific detailed design requirements are suitably applied and fulfilled in application artifacts;

(c) interfaces are developed, agreed upon and implemented into application design artifacts;

(d) design implementation depictions are consistently and clearly represented for installation, construction, testing and maintenance to understand;

(e) reliability, availability, maintainability and safety (RAMS), and security and human factors (usability) are incorporated into the design; and

(f) an auditable design process is carried out.

As a result of the application design stage:

(g) a system integration plan shall be defined:

  (i) unavoidable constraints of integration that influence requirements shall be defined;

  (ii) non-conformances due to integration actions shall be recorded; and

  (iii) all changes to requirements shall be assessed, recorded, approved and traced into the detailed design.

(h) constraints on the design using specific technologies or equipment shall be identified;

> NOTE:
>
> Constraints on design include limitations of selected equipment that could impact the design or maintenance requirements that could be problematic.

(i) the design of a system element shall be completed with all supporting documentation and under version control; and

(j) a system element shall be packaged and stored in accordance with an agreement for its supply.

New designs, alterations to existing designs and deletions of existing systems shall clearly and unambiguously show new, deleted and amended works.

Application design artifacts should not be issued for construction (IFC) or testing and commissioning unless approved in accordance with the DMP.

3.3.2 Rationale

The application design phase involves the production of documents in accordance with the project requirements, identified standards, and other identified information. The documents developed in this stage are then used in the installation and construction, and testing and commissioning phases.

3.3.3 Input artifacts

The application design shall be developed from the documents listed in section 2.3 and section 3.2.5

3.3.4 Requirements

The application design stage shall:

(a) provide clear, accurate, consistent and unambiguous designs;

(b) meet the requirements developed in the scheme design stage;

(c) confirm that the system design will realize the complete set of all allocated requirements;

(d) result in designs that can be used for installation and construction, and test and commissioning; and

(e) develop a functional design that is fit for purpose.

The application design artifacts shall be reviewed in accordance with section 2.6 of this document.

Site visits may form a part of the application design stage for brownfield projects when preparing designs that can be affected by geography and existing infrastructure. This provides an opportunity to assess the geography of the project site, which can be difficult to do based on drawings. Where practical, photographs, drawings, and notes should be taken for reference during signalling design artifact development. Aerial photographs, 3D modelling and other tools may also be used to assess the suitability of the proposed design.

3.3.5 Outputs

The application design stage should deliver the following documents:

(a) Circuit books/sheets.

(b) Data and configuration files.

(c) Cable running plans.

(d) Power supply/voltage drop calculations.

(e) Axle counter overview plan.

(f) Construction scheme plan.

(g) Equipment room layouts.

(h) Output from signal sighting assessments.

(i) Track insulation and/or bonding plan.

Further information on these documents is provided in Appendix C.

These outputs should be subject to stakeholder, production, and independent reviews as described in section 2.11.3

A third-party review may also be necessary (see section 2.11.3.4).

3.4 Installation and construction

3.4.1 Description

The installation and construction stage involves turning the approved designs into physical signalling equipment.

A design schedule may be developed to assist in the timely and logical issuing of design artifacts to the installation and construction personnel.

Design modification could be required during the installation and construction period where issues or errors are identified. See clause 2.9.3.2

Installation and construction should only commence once the application design process is complete and the design artifacts are approved for construction (AFC). Any changes made after AFC should be managed in accordance with clause 2.9 of this document.

3.4.2 Rationale

During the installation & construction phase, inconsistencies or errors could be more apparent with the signalling design. The signalling design process should allow support to either clarify the issue or advise of a rectification in a timely manner that does not impede the project delivery schedule.

3.4.3 Input

The installation and construction phase requires use of all design artifacts developed through the application design phases.

Work packs shall be developed and approved for use in the installation and construction phase.

Artifacts shall be approved for use before construction commences. The typical nomenclature for these artifacts is approved for construction (AFC).

3.4.4 Output

During the installation and construction phase requests for information and installation logs should be developed and actioned as necessary.

At the end of this stage, the signalling system should be constructed with accurate records of what was installed. These records should be reviewed by the signalling designers for any changes. Where significant changes are made to the base design, the design may be altered prior to the testing and commissioning phase. Minor changes that do not affect the testing and commissioning phase may not require changes to the design until after commissioning.

Depending on the project, equipment could be installed on site ready for testing or constructed in a test facility off site ready for testing.

3.5 Testing and commissioning

3.5.1 Description

The test and commissioning stage involves verifying and validating that the system has been built as designed and operates as expected.

Testing includes desktop (e.g. simulations), factory (e.g. factory acceptance testing) and site testing (e.g. site acceptance testing) that occurs prior to the commissioning event.

During the testing stage, modifications to the signalling design could be required due to faults identified during testing and commissioning. Design changes should not be carried out at the commissioning phase.

Test and commissioning requirements are provided in AS 7716 and AS 7717.

3.5.2 Rationale

Whilst the signalling equipment has been built in accordance with the design (and any approved modifications), further changes could be necessary during testing, requiring a level of design support through the testing phase.

During commissioning, additional support should be provided to:

(a) update design artifacts with differences between the tested design and the commissioned signalling system; and

(b) answer queries from the test and commissioning teams.

3.5.3 Input

All final design artifacts (including any design modifications from the installation and construction phase) shall be available. This includes:

(a) the design to be tested;

(b) issue of the design closure list for the commissioning;

(c) responses to requests for information and test logs; and

(d) design modifications.

The designs artifacts to be used for the commissioning phase should be recorded in a design closure list. This list is used by the commissioning team for the commissioning work.

Design support should also be provided during commissioning to check and include any modifications to the design as a result of the commissioning activities, generating interim maintenance copies, and assisting in deployment of design artifacts during the commissioning.

3.5.4 Requirements

Following commissioning, copies of designs required for maintenance shall be made available to maintenance personnel. These are typically known as interim maintenance copies.

Any changes made to the design during commissioning shall be recorded and used to update the design artifacts.

All issues with the signalling design during the testing and commissioning phase shall be recorded. This is typically done using a test log.

3.5.5 Output

At the end of this stage the signalling system should be commissioned into use.

The following outputs should result from the commissioning:

(a) Alterations made during the commissioning captured to produce a record of updates for design.

(b) Interim maintenance copies produced of the commissioned system.

(c) Interim maintenance copies of drawings and data issued to site.

(d) Completed test logs.

(e) Design modifications list.

3.6 Operation and maintenance

3.6.1 Description

Following commissioning, it is important that the source records are updated to reflect what has been commissioned, including traceable information to when it was commissioned. This involves updating all designs to reflect the final, as commissioned, design (referred to as built design) and providing all asset data to the asset owner.

3.6.2 Rationale

To correctly maintain the signalling system, maintenance personnel require accurate, up-to-date, signalling artifacts. Accurate artifacts are also required for use in future projects.

3.6.3 Input

The following artifacts should be provided:

(a) Interim Maintenance copies.

(b) Completed test logs.

3.6.4 Requirements

The as built designs shall be:

(a) updated to truly reflect the configuration of the commissioned system;

(b) updated with commissioning information to provide future traceability of the changes; and

(c) maintained and stored in accordance with the RTOs policies and procedures.

The as built configuration files for signalling data shall be maintained and stored to support system resuscitation during faults.

All logged design defects shall be closed out prior to development of as built drawings.

As built drawings shall be reviewed in accordance with section 2.11 where applicable.

3.6.5 Output

All as built drawings shall be approved and maintained for use.

Appendix A Hazards Register

The following hazards are addressed by this document:

Hazard No.	Hazard Description
9.6.1.1	Equipment not operating as intended and/or equipment failure
9.6.1.2	Equipment not being suitable for a specific use or location
9.6.1.3	Equipment not interfacing with existing equipment/design
9.6.1.4	Equipment not operating as intended
9.7.1.1	Incorrect design resulting in the crossings not operating as intended which, in turn, could result in road or rail collisions
9.7.1.11	Design incorrect and not consistent with existing design
9.8.1.4	Different design implementations for the same configuration but for different equipment leading to later mistakes in installation and maintenance
9.10.1.14	Maintenance not being considered
9.10.1.20	Design not taking account of technology (e.g. tilt masts)
9.10.1.28	Designs not being correct or meeting standards and principles or operations requirements
9.13.1.1	Inadequate interlocking principles
9.13.1.2	Signalling scheme plans which aren't appropriate
9.13.1.3	Inadequate operational requirements
9.13.1.7	Designer and check errors
9.13.1.8	The useability of design and checking tools for signalling design

Appendix B Roles and Responsibilities (Informative)

B.1 Overview

Throughout the signalling design process several key roles exist to ensure the process is followed.

The following roles are generic and are provided with basic responsibilities applicable to the signalling design process only. These roles may have additional responsibilities beyond those shown here.

Note that there may be other roles defined within some organisations.

B.2 Signalling designer

The role responsible for designing signalling sub-systems, circuits and application logic which align with signalling standards and defined operational requirements.

Within a project, additional specialist signalling designers may be required to produce designs specific to their signalling discipline. This may include a principles signalling designer, data signalling designer and communications signalling designer.

The signalling designer is typically responsible for the production check of the design.

B.3 Signalling engineering manager

The signalling engineering manager is a technically knowledgeable person responsible for collating issues and assisting in managing interface integration as well as providing technical input regarding proposed changes of scope and variation requirements.

B.4 Independent verifier

The independent verifier is a person who is independent of the development of the design and is able to objectively review the design without bias.

The independent verifier verifies the signalling design against the project scope, operating requirements, and the applicable signalling principles and standards.

B.5 Third-party reviewer

The third-party reviewer conducts as much verification as they deem necessary (see clause 2.11.3.4), depending on the complexity of the design.

Appendix C Document Description (Normative)

C.1 Overview

This appendix provides information on what information is expected to form the documents referred to throughout this document.

These documents may be compiled into one document or developed into additional documents depending on the scale of the project. Regardless of the document format, it is important that all aspects of the documents described below are captured and recorded.

Specification documents should be developed, reviewed and agreed through a consultative process involving project, engineering, operations and maintenance personnel, as well as representatives from other affected parties. Other parties could include members of the public and road authorities (for level crossings).

C.2 Operational requirements specification

The purpose of the operational requirements specification (ORS) is to provide detail on how the railway is to be operated and maintained following completion of the project. This information is critical to the development of the signalling design.

The ORS builds on the operational requirements definition by adding greater detail.

The operational concept definition and maintenance concept definition should provide the basis for the ORS.

The ORS should include, as a minimum:

(a) train types (passenger, freight, or both);

(b) train frequencies (current and projected);

(c) train speeds;

(d) train schedules (including special and seasonal working, dwell times, etc.);

(e) train headways (current and projected);

(f) shunting requirements;

(g) stabling requirements;

(h) rail traffic crew requirements (change over locations can drive signal location);

(i) maintenance requirements, including:

  (i) signalling system maintenance (maintenance cycles, etc.); and

  (ii) track and infrastructure maintenance (redundancies required due to track closures, etc.).

(j) signalling equipment and type approval;

(k) operational standards, policies and procedures to be followed;

(l) existing signalling configuration (modification and removals);

(m) train protection systems;

(n) headway analysis;

(o) power reticulation;

(p) level crossing systems;

(q) train control systems (including wayside and onboard systems);

(r) cybersecurity;

(s) staging and parallel works system requirement specification (high level);

(t) environmental requirements;

(u) noise considerations;

(v) vandalism consideration;

(w) asset reuse strategy; and

(x) flora, fauna and vermin considerations.

Future planned projects that could impact the signalling design should also be noted.

All requirements should include justifications for the requirement. Where conflicting requirements exist, justifications can assist in prioritization of requirements.

The ORS should be reviewed by operations and maintenance stakeholders, and verified, prior to use in the signalling design.

C.3 System requirements specification

The purpose of the system requirements specification (SRS) is to clearly articulate how the designed signalling system will function, interface with other systems, and the necessary specifications to ensure the system works as intended. The SRS should provide clear detail on the requirements of the systems component of the signalling design and how they interface.

The technical requirements (system level), user requirements specification (URS) and ORS should provide the basis for the SRS. Each requirement within the SRS should be mapped to the associated requirement in the technical requirements (system level), URS and ORS to ensure completeness.

The SRS should detail:

(a) train control system and/or safeworking system to be used;

(b) system architecture;

(c) RAMS requirements to be met;

(d) equipment to be used that is not type approved;

(e) expectations of the system regarding:

  (i) interfaces with other systems (Internal and external);

  (ii) data capture; and

  (iii) degraded mode operation.

(f) maintenance requirements; and

(g) upgrade requirements.

C.4 User requirements specification

The URS provides clear details on the requirements of the users of the signalling system. This may include rail traffic crew, network train controllers, maintenance personnel, or other rail safety workers.

The URS typically covers the human machine interface requirements. These should include:

(a) ergonomic requirements (height of equipment, etc.);

(b) accessibility requirements (for maintenance purposes);

(c) usability requirements (alignment with current policies and procedures).

C.5 Interface requirements specification

The interface requirements specification provides detail on how the system functions are achieved within the system of interest and for interfaces external to the system of interest.

Each interface shall have a defined interface requirement specification to ensure an effective interface is designed.

The following are some of the considerations that could be relevant when defining an interface:

(a) Typical functions passing in each direction.

(b) Method of checking the validity of each function.

(c) Protocols.

(d) Interdisciplinary review requirements.

NOTE:

Non-signalling equipment that could be affected by the proposed work (e.g. power supplies track, etc.) can introduce special risks during the lifecycle of the project.

(e) Interlockings.

(f) Geographical areas.

(g) Track interface.

(h) Level crossing interfaces (traffic signals, advance warning lights, etc.)

(i) Overhead interface (optional).

(j) Tram interface (optional).

(k) RIM's provision at the interface.

The listing and descriptions need to be sufficiently detailed to ensure that the approach and detailed design of each function passing is clearly understood, ensuring a safe and accurate operation of the interface.

For every design output where there is an interface with another discipline (e.g. civil, OLE, track), there should be an interdisciplinary design check to ensure that the interface does not have any impact on the integrity of another rail system.

C.6 Design management plan

C.6.1 Overview

A design management plan (DMP) can be developed at the system requirements definition stage, or at a later stage, depending on the requirements for the DMP. The DMP is a key document for the design definition stage of the signalling design process, so therefore can be developed later if suitable.

The DMP should be produced to align with the project management plan.

The DMP is a live document that is updated as necessary during the project to reflect changes to scope, organisation, responsibilities, standards or changes to the project.

The DMP is a non-technical design management tool used to:

(a) maintain alignment with the overall signalling project management and organizational policies; and

(b) help control scope and design alterations throughout the design process.

Amendments or updates to the design management plan shall be updated in all other concurrent design processes and outputs.

The design management plan shall describe in detail how the project is to be managed. This should include:

(c) how the project is derived from, and aligns with, the timescales, resources and activities in the approved project programme;

(d) how any previously identified non-conformances are managed in design;

(e) information on design authorities and the required competencies;

(f) how a design is issued;

(g) how the project works are approved, based upon correct and complete conformance to the minuted outcome of the design planning meeting;

(h) how the project will (as a minimum) address the design:

(i) control chart (see section C.6.2);

(ii) resource plan;

(iii) responsibilities;

(iv) review process;

(v) development;

(vi) issues;

(vii) change management; and

(viii) deliverables.

(i) the management of:

(i) communications; and

(ii) interfaces and the use of procedures and manuals.

All deliverables shall be produced in accordance with identified standards, meet the approved operations requirements and approved system requirement specification. Deliverable compliance with identified standards shall be traceable.

C.6.2 Design control chart

The design control chart, listing all design items to be prepared with their scheduled date for submission for approval, approval party, shall be included in the DMP.

The design control chart shall include an entry for each type of submission submittable design items for each stage of the works, for each control area and for each phase of design.

The design control chart shall be extracted from the DMP.

The design control chart shall include an allowance for an approval period for each submission and for each resubmission of designs.

The design control chart shall be used for prioritising and programming design checking and approval activities and for monitoring the design progress.

C.7 Signalling functional specification

The signalling functional specification (SFS) details the technical elements required for the signalling design. This may be developed as a signalling requirements and operations specification.

The SFS should be developed from the system and sub-system requirements specification (see Section 2.2)

Once the SFS documentation has received formal acceptance, any changes required to design inputs shall be managed under an agreed control process.

The SFS shall specify the standards applicable to the project, including any deviations or derogations.

The SFS should include (where applicable) the technical requirements for the:

(a) signalling requirements;

(b) required stage works;

(c) interfaces (see Appendix D);

(d) how the operational, use, and maintenance requirements are to be met;

(e) installation methodologies;

(f) identify any non-compliances with referenced standards; and

(g) identify any signalling equipment that is not type approved;

NOTE:
Type approval process is described in AS 7702.

C.8 Signalling arrangement plan

The signalling arrangement plan (SAP) is also known as the signalling schematic.

The SAP shall be assessed against the ORS to ensure all project requirements are met.

Where the signalling project is divided into sequential commissionings, staged SAPs shall be created for each commissioning. All proposed stages of the design shall be detailed and all configuration changes clearly listed.

The SAP typically includes:

(a) Tracks (usually shown as a single line):

  (i) Turnouts are shown with a gap between the normal and reverse positions to clearly differentiate between the two; and

  (ii) Tracks are usually shown as a straight line (curvature is not generally shown unless for a balloon loop or triangle).

(b) All major structures (bridges, tunnels, platforms, etc.). The location (reference distance) should be shown.

(c) Signalling infrastructure. This will vary depending on the signalling system, but may include:

  (i) signals;

  (ii) train protection equipment;

  (iii) wayside cab signalling equipment (balises, etc.);

  (iv) point motors;

  (v) lever frames;

  (vi) axle counters/track circuit limits; and

  (vii) signage (directly relating to the signalling design).

(d) Level crossing activation points and times, including any related track circuits.

For brownfield sites, an initial site assessment of the sighting of lineside signals, signs and indicators should be undertaken as soon as practicable following development of the SAP.

A recent gradient site survey plan should be provided as an input into the SAP. The gradient information should be used assist in determining risks of PAE events due to signals being positioned on steep grade or risks associated with rollback. Braking and acceleration changes based on the impact of rising or falling grades that could impact signal spacing and the impacts of grades when determining the stopping position of rolling stock after an enforced stop should also be assessed.

C.9 Aspect sequence charts

The aspect sequence chart identifies the aspect sequence between signals. The chart shows all signals for a given direction of travel, their aspects and the interconnection between aspects in following signals that provide the advance signalling.

C.10 Construction scheme plan

The construction scheme plan (CSP), also known as a site survey plan, provides the location of:

(a) location cases (including showing the area of control);

(b) power supply locations;

(c) signals;

(d) pits;

(e) cable routes; and

(f) existing cables (with notes on cables to be removed or relocated).

Whilst the CSP typically will be drafted as part of the architecture definition stage, it is usually finalized during the design definition stage. Early development of the CSP can assist with 3D modelling and desktop signal sighting assessments.

A recent kilometre post or reference survey point shall be obtained as a basis for the construction scheme plan.

C.11 Control tables

Control tables are a structured tabular presentation of the dependencies that need to be met to allow the setting, locking and releasing of points and other moveable infrastructure, and signalled routes. The specific information provided in the control tables will depend on the signalling system being used.

This information is derived from the SAP, SFS, signalling principles, and the operational requirements specifications, and informs the development of the interlocking data that is vital to the safety of the signalling system.

During development of the control tables, it could be identified that an alteration to the SAP is necessary. Therefore, it can be beneficial to develop the SAP concurrently with the control tables.

It is important that the control table design is progressed sufficiently before data and/or circuit design work commences. During the data/circuit design, it could be necessary to alter the control tables, however, this should be avoided where possible.

C.12 System architecture

The system architecture defines the signalling system architecture, including the network communications relevant to the signalling design. Where a new system of safeworking is being introduced, that system should also be included in the system architecture design.

The system architecture is closely aligned with the SAP and SFS, and includes information that helps verify RAM targets being met, and that cyber-protection provision is suitable and integratable.

The system architecture should include descriptions and definitions of the:

(a) interconnectivity to the:

  (i) signalling control & indication systems;

  (ii) maintenance and diagnostic information systems;

  (iii) interlocking systems;

  (iv) object controller systems;

  (v) train detection systems; and

  (vi) trackside equipment.

(b) security (cyber) requirements.

C.13 Equipment room layouts

The layout of equipment rooms can be drafted as part of the architecture definition process. This enables the size of the rooms to be determined and allowed for in the infrastructure construction component of the project.

Whilst specific equipment rack design is not required at this stage, a general arrangement of the racks can assist in determining the space required.

C.14 Bonding plan

The bonding plan (also known as a track insulation plan) clearly articulates what insulation and bonding is required in the track design.

The bonding plan shall show all rails (not use a line drawing) as some bonds/insulations may only be on one rail.

The bonding plan shall show both parallel and series bonds.

The track equipment such as points and point machines, and train detection system limits, for example track circuit joints, audio frequency tuned loops, axle counter wheel sensors, train protection systems and impedance bonds (if required) shall be shown.

Limit of authority locations (signals, stop boards, etc.) shall be shown. The relationship with associated insulated track joints shall be shown.

Where overhead electrification is used, the location of bonds and earths for all associated electrical installations shall be shown.

C.15 Axle counter overview plan.

This is a high-level diagram showing the connections between all axle counter sub systems and connections to the wheel detector. The axle counter overview plan shall assess how features on axle counters such as double usage head and supervisory sections are used. The axle counter overview plan should be used to assist with the resetting design of axle counter sections.

The axle counter overview plan should include (but is not limited to):

(a) wheel detector positions;

(b) wheel detector identification;

(c) track section number;

(d) supervisory section allocation (if applicable);

(e) double usage head control (if applicable);

(f) what evaluator is counting which head;

(g) system address;

(h) system dip switches/jumpers (if applicable); and

(i) controlling computer based interlocking (if applicable).

C.16 Power calculations

Calculations should be done for:

(a) total standing load for each power equipment room;

(b) total dynamic (transient) load for each power equipment room;

(c) total standing load for each feeder;

(d) total dynamic (transient) load for each feeder;

(e) voltage drop on each feeder to determine minimum cable size; and

(f) fault loop impedance.

Calculations should detail:

(g) each feeder;

(h) locations fed from the feeder;

(i) distance between locations, assessing cable route and % increase for deviations;

(j) VA rating for each device; and

(k) protection device rating to ensure adequate fuse discrimination.

C.17 Circuit sheets (books)

Circuit sheets shall show all wiring, cable and hardware configurations. They shall also detail all fuses, terminals, cable cores, I/O and relay contact allocation (e.g. analysis sheets).

All equipment shall be uniquely identified

Circuit sheets can be combined into a circuit book.

C.18 Data and configuration files

The type of hardware will determine the type of data and configuration files required. All personnel modifying or verifying the data shall be competent for that system.

The following data should be developed:

(a) Interlocking data (including object controllers).

(b) Configuration data.

(c) Level crossing data (if applicable).

(d) Axle counter data (if applicable).

(e) Telemetry data.

(f) Control system data.

Appendix D Business Case and Scope Review (Informative)

It is expected that the business case, project scope and budget is reviewed for practicality of design, commissioning, operation, and maintenance prior to being accepted for use in the signalling design process.

The business case and project scope for a signal design project is initially determined to meet specific operational or technical requirements. This can be limited by the focus on these issues. The overall objective is to design a signalling system that is safe for the rail operations, complies with the SMS of the RTO, and is fit for purpose. The following actions can be undertaken to assist in meeting these objectives:

(a) Review of the existing infrastructure against the current engineering standards, and any changes to the engineering standards since the original construction of the signalling system are identified. This could result in the existing signalling system also having to be upgraded to meet the requirements of the current standards. Unless a concession, derogation or waiver is approved, then this upgrade would be included within the project scope of works.

(b) The project scope is often focused on the project geographical scope. However, the signalling system integrity extends beyond the nominal geographical scope. The signalling system needs to be considered as a whole, not just the part identified for the project work.

For example, a project may nominate the extension of a crossing loop at one end to allow for longer trains. The design project should also review the full interlocking including the other end of the crossing loop, as this could require evaluation of the braking distance and signal spacing at the other end of the crossing loop to be appropriate for the braking distance requirements for the longer train.

Similarly, changes to an automatic signal section for faster trains, more trains or shorter headway would need to evaluate the impact on the full automatic signal section of these changes. This could require an increase in scope to provide a consistent signalling system operational performance across all of the automatic signal section.

(c) An existing signalling system could have latent defects. The review of the status of the existing signalling design artifacts or the undertaking of the new design can identify these latent defects. The scope of work to correct these defects would need to be documented and potentially form part of the new signalling project works.

Bibliography

The following referenced documents are used by this document for information only:

- AS 7739.1, *Digital Engineering for fixed rail infrastructure Part 1: Concepts and principles*