The PRT Project
Phase 1 Design & Engineering

PRT Safety Concept

Title/Name of delivery:	PRT Safety Concept
Document ID:	1-ABC-6-8-1.0
Version:	1.0
Date:	17.04.03
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Security:	Confidential

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1 Executive Summary

The project has established a safety vision and safety objectives for the PRT system:

Safety Vision
Ensure safe and efficient traffic in an environmental friendly manner. Personnel Rapid Transport (PRT) must not result in loss of human life, serious human injury or serious damage to material or the environment. (The 0-vision).

Safety Objectives
The PRT will be designed and constructed according to the following safety principles:

The PRT system will be at least as safe as comparable modern transportation systems.
All design decisions will be based on the ALARP principle, i.e. the risk for loss of lives or major injuries shall be as low as reasonable possible.
No single failures shall lead to severe accidents.
The double barrier may be of technical and/or procedural nature.

The objectives are fulfilled through:

- Designing in accordance with National and International standards. The standards are to be accepted by the relevant Railway Inspectorate
- Establishing a Safety Management Program and including safety in every aspect of the project.

Authority regulation as well as industry standards (National and International)

Tailor made regulations and safety standards for PRT-systems do not exist. Even though a PRT system has many features that are significantly different from traditional rail systems, it utilises self propelled vehicles on a fixed guideway and the system will for most countries fit under the regulations for railways, metros or trams.

The authority regulation and guidance for railways have to be applied with a significant degree of flexibility for a PRT system, but many requirements and safety principles for railways and similar systems can be applied to a PRT-system. Regulations and guidances in some countries (e.g. Germany, UK and US) have special requirements for automatic train (vehicle) operation within their regulations.

The most complete standard for mass transit automatic passenger movement is the ASCE standard for Automated People Mover Part 1-3. The standard includes minimum requirements for the design construction, operation and maintenance of the various parts of an APM system and is in general also relevant for a PRT-system. The standard has no legal authority in its own right but may acquire legal standing in one or more of the following ways:

- Adoption by an authority having jurisdiction
- Reference to compliance with the standard as a contract requirement
- Claim by a manufacturer or manufacturer's agent of compliance with the standard

We will recommend that this standard is specified as the main standard for the FlyBy PRT.

Safety Management Program

The objective of the safety program is:

to ensure the realization of the project
to ensure adequate safety throughout the lifecycle of the PRT

The primary tasks of Safety Management Program are to establish a Safety Management Organisation and a Safety Management System. The Safety Manager should at an early stage contact the local authorities to get an understanding of the local requirements. Upon initiating the next phase of Fornebu FlyBy pilot, a primary task is sending an initial application for the transportation system to the Norwegian Railway Inspectorate.

Safety approval of the traffic control and protection systems

This is an item of great concern.

A suite of European standards EN 5026, EN 50128 & EN 50129 have been developed by CENELEC for railway applications covering overall safety of railways and the safety, reliability and integrity of control and signalling systems for railways. The standards are open and process oriented, i.e. they are not prescriptive in terms of applicable or mandatory solutions, but describe how functional safety requirements shall be set and verified.

Strong criticism has been raised against these standards by parties that have applied them for entire new transit systems or new control and signalling systems. Among the objections are the time consumption and cost of the processes specified by the standards in relation to the overall safety verification of the systems, software and hardware developed according to the standards. However, the codes may be difficult to get around as they are directly specified by authorities and inspectorates of many countries.

It has been stated that the validation, assessment and approval process for a SIL 4 system can take as much as two years and cost in the range of 20 – 50 million NOK.

2 Introduction

2.1 Purpose

The purpose of establishing a safety concept in the concept phase of the PRT design project is to raise the awareness and understanding of safe design work processes for all participants in the project.

Creating a safe and efficient transport system is a main design philosophy for the PRT project. The Safety concept shall provide tools and guidance for handling safety issues in the project. The safe design work processes shall be simple to use and to verify.

2.2 Scope

The scope of this document is to describe the safety Concept for the PRT/FlyBy system.
The Safety Concept includes the following:

- The main safety principles and guidance for use in later project phases.
- The main framework for the activities needed to demonstrate that the PRT/FlyBy system is able to achieve an acceptable safety level, i.e. illustrate the work processes and activities needed in order to achieve authority approval.
- A recommendation for applicable safety standards.
- Overview and description of the most important safety issues.

A main success criterion for this 1st Phase Design & Engineering Project is that the project steering committee finds the proposed safety concept trustworthy and achievable.

3 Safety Concept

3.1 Safety Vision

Ensure safe and efficient traffic in an environmental friendly manner. Personnel Rapid Transport (PRT) must not result in loss of human life, serious human injury or serious damage to material or the environment. (The 0-vision).

3.2 Safety Objectives and Principles

The PRT will be designed and constructed according to the following safety principles:

The PRT system will be at least as safe as comparable modern transportation systems. Please refer to Appendix for statistics for operating systems.
All design decisions will be based on the ALARP principle, i.e. the risk for loss of lives or major injuries shall be as low as reasonable possible.
No single failures lead may to severe accidents.
The double barrier may be of technical and/or procedural nature.

The objectives are fulfilled through:

Designing in accordance with National and International standards. The standards are to be accepted by the relevant Railway Inspectorate
Establishing a Safety Management Program and including safety in every aspect of the project:

- Include safety aspects in the design phase from the conception and design of the transport system and through the whole life cycle of the system (construction, use, maintenance and final disassembly).
- Raise the awareness and understanding of safe design work processes for all participants in the project. All design and construction activities must be geared towards improving safety.
- Provide documentation of the life cycle safety aspects of the Joint Venture PRT transport system to all stakeholders.

4 Applicable Safety Standards for a PRT system

PRT is a new transport system without many industry standards nor tailor made rules and regulations from regulatory authorities. Even though a PRT system has many features that are significantly different from traditional rail systems, it utilises self propelled vehicles on a fixed guideway and the system will for most countries fit under the regulations for railways, metros or trams.

Below is identified some international and European industry standards that can be made applicable to a PRT-system, as well as applicable government authority regulations and guidance for some important countries:

4.1 International and European industry standards

A suite of European standards have been developed by CENELEC for railway applications. A list of the EN-standards for railway application is included in Appendix 4. Among the most relevant for a PRT-system are the following:

a) EN 50126: Railway applications – The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS). CENELEC, September 1999.
b) EN 50128: Railway applications – Communications, signalling and processing systems – Software for railway control and protection systems. CENELEC, March 2001.
c) prEN 50129: Railway applications – Safety related electronic systems for signalling. CENELEC, December 1999 (draft)
d) EN 50159-1: Railway applications – Communication, signalling and processing systems – Part 1: Safety-related communication in closed transmission systems.
e) EN 50159-2: Railway applications – Communication, signalling and processing systems – Part 2: Safety-related communication in open transmission systems.

In particular the EN 50126, EN 50 128 & EN 50 129 are central for the overall safety of new railway developments, as well as for their control and protection systems. The standards are open and process oriented, i.e. they are not prescriptive in terms of applicable or mandatory solutions, but describes how functional safety requirements shall be set and verified, and further describes a validation and independent assessment process for the system development.

EN 50126 addresses system issues on the widest scale, while EN 50129 addresses the approval processes for individual systems which may exist within the overall railway control and protection system. EN 50128 concentrates on the methods which need to be used in order to provide software which meets demands for safety integrity which are placed upon it through the processes described in EN 50126 & EN 50129. The key concept of these European Norms is that of safety integrity levels (SIL). A safety function should be allocated a SIL-level depending upon the risk and consequences related to the failure of the safety function, and the safety requirement (reliability requirement) for that specific function are then determined from the specified SIL-level.

Signalling and rail traffic controlling systems are normally allocated a SIL-4 level which puts very strong requirements on the developer and operator in proving hardware and software integrity. The tolerable hazard rate according to EN 50129 for a safety function allocated a SIL-4 level is 10^{-5}-10^{-4} per year and function, i.e. an accident due to failure of this safety function should not be more frequent than 1 per 10 000 or 1 per 100 000 year. Such strong integrity levels can be difficult to obtain, prove and verify.

Comments:
The above discussed EN standards are quite new and the various parties in the industry have not developed a clear understanding of their functioning, and the associated implementation processes. Strong criticism has therefore been raised against these standards by parties that have applied them for entire new transit systems or new control and signalling systems, and there is a consensus within the industry that further guidelines on application of these standards are required. Among the objections are the time consumption and cost of the processes specified by the standards in relation to hazard analysis, verification, validation and assessment of the systems and hardware developed according to the standards. It has been stated that the validation, assessment and approval process for a SIL 4 system can take as much as two years and cost in the range of NOK 20 – 50 million. However, the codes may be difficult to get around as they are directly specified by authorities and inspectorates of many countries.

The above railway application standards are developed in line with the more general standard for development of safety critical software:

- *IEC 61508 Parts 1 to 7: Functional safety of electrical/electronic/ programmable electronic safety-related systems; IEC, 2000.*

For a PRT system it should therefore be possible to utilise the IEC 61508 set of standards instead of the specific railway application standards EN 50128 & EN 50129. However, that may require approval of the relevant national authority e.g. Railway Inspectorate.

4.2 United Kingdom

The **HM Railway Inspectorate** in UK has issued a set of documents giving safety principles and guidance for railway systems*: Railway Safety Principles and Guidance; Health and Safety Executive, HM Railway Inspectorate (UK).*

The publication is intended to give guidance and advice to those involved in the design and construction of new and altered works, plant and equipment affecting the safety of railways, tramways or other guided transport systems.

The document is not intended to set out mandatory standards. It describes the aspect of safety which HM Railway Inspectorate of the Health and Safety Executive would expect to see considered in railway works, plant and equipment to provide an acceptable level of safety for any people affected. The document is divided into two parts, where part 1 sets the principles and Part 2 gives guidance and advice on how these principles can be achieved. Part 2 consists of 8 separate publications addressing various issues as: infrastructure, stations, electric traction system signalling level crossings trains etc.

The scope of the document covers all types of work, plant and equipment that may be found on all guided transport systems including mainline (heavy) railways, mass transit, light rail, tramway and heritage systems.

The principles are intended to apply to funiculars and other guided transport systems only to the extent that is appropriate taking into account the special features with the system concerned may possess. By "other guided transport system" is meant a system, other than a railway or tramway, where the vehicles operating on it are guided by means external to the vehicles. It is stated that the term therefore includes monorails and airport transit systems.

The main safety principle of the documents is that the system should be safe, and in order to ensure this, all intolerable risks shall be eliminated and all remaining risk have been reduced to as low as reasonable practicable (known as ALARP). Both internal and external hazards should be considered.

In considering how to implement these principles, care should be taken to:

a) identify the complete range of foreseeable hazards;
b) assess each hazard and establish its importance;
c) provide means of preventing or controlling the hazard if appropriate;
d) provide a means of mitigating the effects of the hazards in appropriate ways; and
e) provide a means of recovery from the hazard, if appropriate

Most of the principles specified are of a rather general nature and are not specific for HMRI and the UK. The majority of them are more or less self evident and apply equally well to a PRT-system as a traditional rail or metro system.

The guidance documents are more specific and many of the detailed specifications are not applicable to a PRT system. However, some are very relevant as indicated in Appendix 2.

4.3 Germany

BO-Strab (Bundesordnung über den Bau und Betrieb der Strassenbahnen) is a federal code for trams, metro and light rail in Germany. The code is explicitly said to apply also to driverless systems. Hence, the code mentions specific requirement for driverless systems, but there is also issued further guidance documents for driverless system.

Among those are:

a) Vorläufige Richtlinien für den Fahrbetrieb ohne Fahrzeugführer nach der Verordnung über den Bau und Betrieb der Straßenbahn (BOStrab-Richtlinien für den Fahrbetrieb ohne Fahrzeugführer)
b) VdV- Schriften 399, Anforderungen an Einrichtungen zur Gewährleistung der Fahrgastsicherheit in Haltestellen bei Fahrbetrieb ohne Fahrzegführer, Verband Deutscher Verkehrsunternehmen, Oktober 2000.

The German rules have also been applied for systems outside Germany, e.g. for the driverless Copenhagen Metro. A full list of the BO-Strab specific requirements of the code are presented in Appendix 2.

The VdV- Schriften 399 gives guidance on how stations and platform arrangement can be made safe for automatic operation without utilising platform screen doors.

4.4 United States

4.4.1 Federal authorities

In the United States there are no federal law and regulation specifically addressing the safety of mass transit systems either being traditional metros, light rail transit systems, automatic people movers (APM) or personal rapid transit (PRT) systems. The Federal Transit Administration is the administrator of the federal policy on urban mass transit, and the Administration has a number of safety projects and programs ongoing. Results from such projects and programs are published and provides guidance on how to handle safety in various mass transit systems. Among the publications are:

- *Handbook for Transit Safety and Certification; FTA, Office of Safety and Security; DOT-FTA-MA-90-5006-02-01, DOT-V-NTSC-FTA-02-01*
- *Hazard analysis Guidelines for Transit Projects; FTA, Office of Safety and Security; DOT-FTA-MA- 26-5005-00-01, DOT-VNTSC-FTA-00-01*

However, none of the above publications have any mandatory or legal authority. The handbook and guidelines are published by FTA to assist the transit industry as well as state and local organizations in providing a high level of safety and security for passengers and employees of the mass transportation systems.

4.4.2 ASCE; Automated People Mover Standards – Parts 1-3

This standard has been prepared by the ASCE (American Society of Civil Engineers) Automated People Mover Standards Committee. It establishes the minimum set of requirements necessary to achieve an acceptable level of safety and performance for an APM system. An APM is defined as a guided transit mode with fully automated operation, featuring vehicles that operate on guideways with exclusive right-of-way. The overall goal of this standard is to assist the industry and the public by establishing standards for APM systems. As such it may be used in the safety certification process.

The title and content of the 3 parts are as follows:

- *APM Standards – Part 1: Operating environment, Safety requirements, System dependability, Automatic Train Control (ATC), Audio and visual Communications; ASCE 21-96*
- *APM Standards – Part 2: Vehicles, Propulsion and Braking; ASCE 21-98*
- *APM Standards – Part 3: Electrical, Stations, Guideways; ASCE 21-00*

Part 1 of the Standard, provides general information and definitions followed by discussions of the operating environment, safety requirements, system dependability, automatic train control subsystems, and audio and visual communications.

Part 2 provides general information on vehicles and Propulsion and Braking Systems (PBS). Topics dedicated to vehicles include vehicle capacity and load, structural design, coupling, fire protection, and electrical systems. PBS topics include methodology, functions, component design and testing.

Part 3 provides information on electrical equipments, stations, and guideways including emergency evacuation and access as well as structural design criteria for the guideway.

The standards are not particularly detailed or specific, but are clearly the most comprehensive set of standards for a fully automatic public transport system. On many aspects reference is made to other standards and specifications as NFPA Publications for fire safety and Military Standards for developing System Safety Program and Hazard Analysis.

The standard includes minimum requirements for the design construction, operation and maintenance of APM systems. The standard has no legal authority in its own right but may acquire legal standing in one or more of the following ways:

- Adoption by an authority having jurisdiction
- Reference to compliance with the standard as a contract requirement
- Claim by a manufacturer or manufacturer's agent of compliance with the standard

We will recommend that this standard is specified as the main standard for the PRT Fly By. It may not be comprehensive enough as a stand alone standard for specification and approval of control system and automatic train protection although it makes reference to US Military specifications.

For application outside US a reference to EN 50125/128/129 or IEC 61508 would be required.

4.4.3 NFPA-130: Standard for Fixed Guideway Transit and Passenger Rail Systems

The standard covers fire protection and fire life safety issues and is applicable to any fixed guideway transit and passenger rail system including Automated Guideway Transit. The standard is prepared by the National Fire Protection Association, Inc in the United States and is approved as an American National Standard. The NFPA standards are also frequently used outside the United States, and the NFPA-130 was used in the Copenhagen Metro project.

Some of the specific requirements applicable for an automated guideway transit system as the PRT Fly By is specified in Appendix 2.

The NFPA-130 standard is referenced by the APM standards issued by ASCE.

4.5 Norway

Statens Jernbanetilsyn (Railway Inspectorate) is the governmental authority for railways in Norway and has the responsibility to supervise safety for new and existing railway lines and other fixed guided transport modes in Norway. According to comments from the department, the intention is that all fixed guided installations for public transport come under the definition of railways and are under the auspices of Statens Jernbanetilsyn apart from the following exemptions:

- *Inspection and control of cableways are covered by Taubanetilsynet carried out by Det Norske Veritas.*
- *Roller coasters and other track guided installations in amusement parks for leisure activities.*
- *Track guided transport in mines and closed industrial areas.*

There are of cause possibilities for having a PRT-system exempted from the railway legislation and the authority of the Railway Inspectorate, but we can not see a strong motivation for this and find it unlikely that such an exempt is granted.

The Statens Jernbanetilsyn requirements to railway systems as well as guidance for approval of new railway systems (infrastructure) are specified in the following documents:

- *Forskrift om krav til jernbane, herunder sporvei, tunnelbane og forstadsbane m.m. (kravforskriften), FOR 2001-12-04 nr 1334; Statens Jernbanetilsyn*
- *Veiledning til prosess for godkjenning av kjørevei; Utgitt av Statens Jernbanetilsyn 20.11.2002.*

Kravforskriften (the requirement specification) is mainly directed towards traditional rail system and most of the specifications are not directly relevant for a PRT-system or are of a general and obvious nature. Some generic requirements that are applicable to an automated PRT-system worth mentioned are the safety principles specified in Section 3.2 of this report:

- *Continuous improvement*
- *ALARP-principle*
- *Barriers against single failure accidents*

Of more specific requirements that are relevant also for a PRT-system are:

Infrastructure (guideway and stations):

- *It shall be possible to evacuate a train in a safe manner on bridges and viaducts. Walkways on bridges and viaducts shall be equipped with a parapet or banister to prevent people from falling down.*
- *Fixed infrastructure and their equipment shall be so designed and arranged that they can be inspected and maintained without undue risk to personnel.*

Vehicles:

- *To be designed for accident load*
- *Safe doors, windows and interior*
- *Specified safety devices for doors*
- *Emergency braking arrangement*
- *Parking brakes.*

Traffic control and protection:

- *Traffic control shall be based on track block principles, and the risk of two trains occupying the same track section should be controlled and safeguarded by technical systems.*
- *Trains and vehicles shall always be able to stop within the track distance to the next train and within distance of free sight along track.*

The SJT Guidance on approval of new infrastructure is commented in Section 5.4 of this document and is copied in Appendix 5 of this report.

5 Safety Management Program

The objective of the safety management program is:

to ensure the realization of the project
to ensure adequate safety throughout the lifecycle of the PRT

The safety program must include a description of the concept and its boundaries at a sufficient level to enable the other safety lifecycle activities to be satisfactorily carried out. The PRT project concept should be divided into appropriate systems and described accordingly:

Infrastructure
- Station
- Guideway
- Traction

Vehicle
Control system

5.1 Overall safety lifecycle – Work Process

The overall safety lifecycle of the project, describing the activities necessary to demonstrate acceptable safety, is illustrated below.

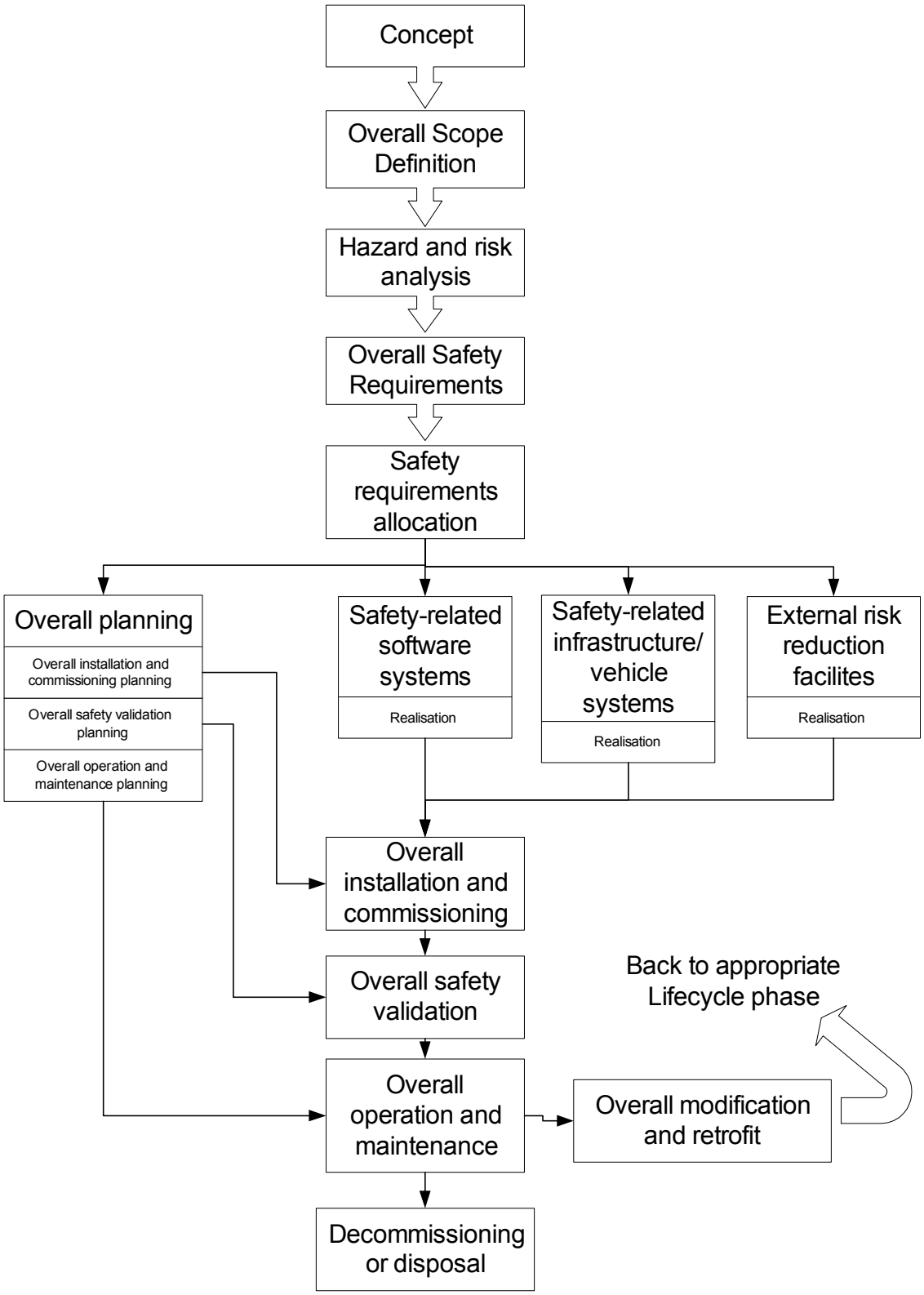

Figure 1: Overall safety lifecycle

The activities during the overall safety lifecycle are described in more detail in the table below:

Safety lifecycle phase	Objective	Activities related to verification, management of functional safety and functional safety assessment
Concept	Develop understanding of: • The technical system; the PRT transportation system including infrastructure, vehicles and traffic control system. • The environment (physical, legislative, etc)	• Establish safety policy and safety targets • Perform coarse evaluation of project safety implications.
Overall Scope definition	Specify scope of Hazard and Risk analysis	• Establish safety plan. The objective of the safety plan is to describe how the project works with safety. The safety plan should include overall planning of safety validation activities for: Design, testing and production Operation and maintenance Installation and commissioning Training • Establish sub-system structure for hazard and risk analysis. • Specify external events to be taken into account in the hazard and risk analysis
Hazard and risk analysis	Determine hazard events and analyse risks for all reasonably foreseeable circumstances.	• Perform an analysis that identifies the hazards associated with the PRT. • Determine the sequence of events leading to the hazardous events • Evaluate the associated risk(s), based on determination of likelihood and potential consequences associated with the hazard event. • Identify measures to eliminate or reduce risk. • The level of details of the analysis depends on the phase of the project. Hazard tracking will be performed on Concept level and Subsystem level. Hazard identification will be performed for the entire life cycle of the project: Design Construction

		Operation Disposal • The hazard and risk analysis provides an input to which systems there may be a need for establishing safety requirements.
Overall safety requirements	Develop specification for overall safety requirements.	• Define overall safety requirements and safety acceptance criteria. o Define necessary safety functions o Identify all safety-related systems o Define safety integrity requirements for each safety function. • Establish system for safety management (Hazard identification, risk analysis and follow-up system) The safety management system must also handle interface problems between the various design teams
Safety requirements allocation	Allocate safety integrity level to each safety function.	• Specify sub-system and component safety requirements • Define sub-system and component safety acceptance criteria. • The safety requirement allocation is iterative, and if it is found that the necessary risk reduction for a safety function cannot be met, then the architecture shall be modified and the allocation repeated. • Update safety plan
Overall planning	Develop plans: • To facilitate overall safety validation of safety related systems • To ensure that systems are constructed and installed in a manner so that that the functional safety is achieved. To ensure that required functional safety is maintained during operation and maintenance	The plans are made to ensure that the required functional safety is achieved and maintained, and to facilitate the safety validation. This is a continuous process and needs updating after each step.
Overall design and realisation	Create systems that meet the safety integrity requirements.	Implement safety plan: • Safety-related design decisions shall be justified through hazard

		identification and risk analysis • Follow-up safety management (Regular update of hazard log, evaluation of risk and implemented risk reduction measures)
Overall installation and commissioning	Assemble and install systems (in a manner satisfying the functional safety requirements)	Follow-up safety management (Regular update of hazard log, evaluation of risk and implemented risk reduction measures)
Overall safety validation	Validate that safety related systems meet the overall safety requirements.	The validation process shall be based on the following principles: • The validation process shall be based on a systematic approach • Possible hazards shall be identified, and risk of these hazards shall be determined • Risk analysis, measurements and tests shall be used as main tools to document that design, production and construction fulfils the specifications.
Overall operation, maintenance and repair	Operate the systems in a manner ensuring that the overall safety requirements are maintained.	Follow-up safety management (Regular update of hazard log, evaluation of risk and implemented risk reduction measures). Safety-related design decisions shall be justified through hazard identification and risk analysis
Overall modification and retrofit	To ensure that functional safety is appropriate both during and after modifications.	Follow-up safety management (Regular update of hazard log, evaluation of risk and implemented risk reduction measures)
Decommissioning or disposal	To ensure that functional safety is appropriate both during and after the activities of decommissioning or disposal.	Follow-up safety management (Regular update of hazard log, evaluation of risk and implemented risk reduction measures)

5.2 Safety Management Organisation

A responsible Safety Manager for all safety activates for all design disciplines must be appointed. The Safety Manager is responsible for establishing safety plans and follow-up of the safety management. This includes but is not limited to the following actions:

- regular update of hazard log,
- evaluation of risk and implemented risk reduction measures,
- follow up of general process quality procedures according to given SIL.

The Safety Manager is responsible for contact with local authorities and to establish a strategy for Authority approval. If the local Authorities prefer to use an independent Assessor to review safety documentation as part of the Approval process, the Safety Manager is responsible for establishing and follow-up contact with the independent Assessor.

Each member of the project team has a role in safe designing and safety validation. While the Safety Manager has primary responsibility for Safety Management, the tasks required to perform the Safety Management Program include many functional disciplines on the project team.

As indicated in Figure 2, the Safety Manager should support a coordinated effort that brings the capabilities and resources of the design team, the construction team, the acceptance and verification team, and the activation team to the performance of Safety Management activities.

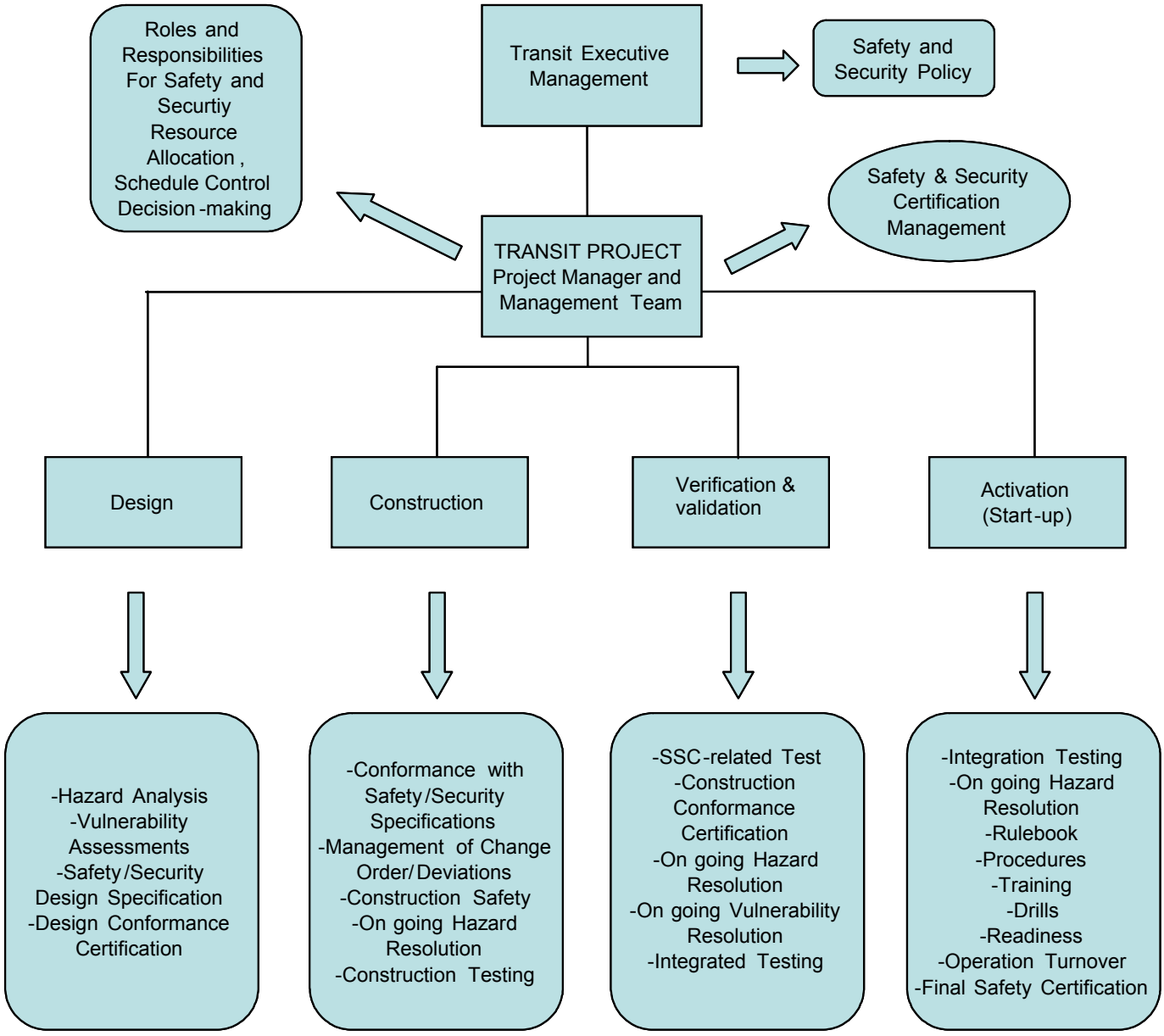

Figure 2 The tasks required to perform the Safety Management Program include many functional disciplines on the project team

5.3 Safety Management System

The Safety Manager is responsible for establishing a follow-up-system of safety issues to ensure that the design conform to the safety requirements. The main principles of a Safety Management System are illustrated in Figure 3:

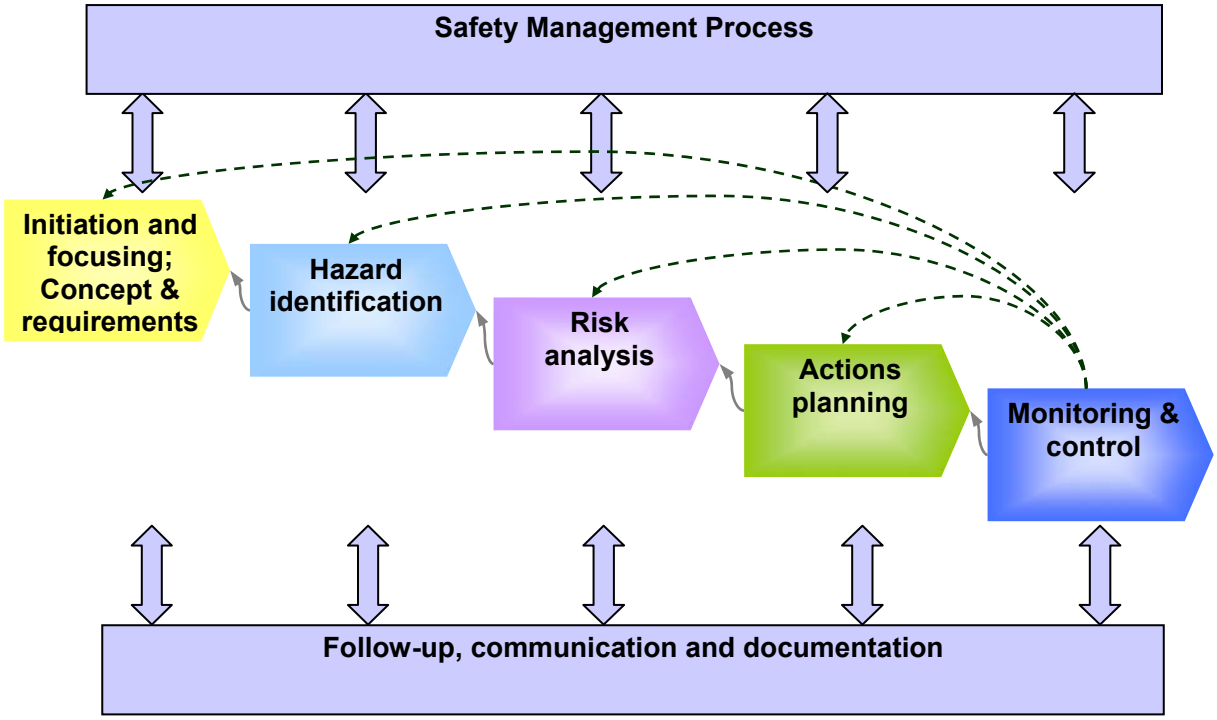

Figure 3 Illustration of Safety Management System

The main standards referred to in this document are suggesting a Safety Management System similar to the system illustrated above.

5.4 Approval Strategy

Even though a PRT system has many features that are significantly different from traditional rail systems, it utilises self propelled vehicles on a fixed guideway and the system will for most countries fit under the regulations for railways, metros or trams, and an application for Approval should thus be directed to the Railway Inspectorate.

The Approval Process may vary for the different countries, and the Safety Manager should thus at an early stage contact the local authorities to get an understanding of the local requirements.

There is a large variety of standards and norms, and the project should base the design on standards and norms that covers the totality of all safety issues and also are broadly accepted, as this will facilitate the approval process for the subsequent local projects.

5.4.1 Fornebu Pilot

A guideline for the approval process for the FlyBy pilot at Fornebu, based on the Norwegian Railway Inspectorate (NRI) document "Veiledning til prosess for godkjenning av kjørevei" (Guideline to process for approval of infrastructure), is given below.

The Railway Inspectorate shall approve the system infrastructure before operation may commence. The infrastructure comprises the guideway with structures and arrangements, signal and control-system, power supply and communication systems.

The formal application for approval shall be sent from the Manager of the PRT development. The applicant is also responsible for getting approval from other Authorities as the Directorate for Fire- and Electrical Safety (DBE) and Inspectorate for Mail- and Telecom.

Initial Application

If the Railway Inspectorate is involved at an early stage of the planning process, the approval process will usually be smoother and the need for documentation may be reduced. The Inspectorate recommends that an initial application is sent in the early design phase. The initial application should, according to NRI, include the following:

- Contact persons
- Progress plan – not detailed, but sufficient for Inspectorate to plan resources
- Project Description – concept description including alternatives
- Overview of standards and norms to be applied in the project, and basis for selection of standards.
- Description of Safety Management Systems – Overview of Safety Management Competence, Safety Organisation, etc
- Safety plan – Overview of planned safety activities, including verification and validation processes, safety documentation
- Safety evaluation – Concept Safety Analysis and preliminary Hazard Analysis. The results must be compared with safety requirements.

Use of independent Assessor

The Inspectorate may require that an independent body is performing an independent safety evaluation of the transportation system. *This will particularly be relevant when introducing new technology.*
The applicant will thus be responsible for having an independent review, and appointing an assessor.

Project changes

Project changes shall be reported to the Inspectorate. This includes changes of concept, of main infrastructure systems and changes of applied standards.

Project progress

Main project progress should be reported to the Inspectorate. The following progress should be reported:

- Start-up of detailed design
- Start-up of construction. The Inspectorate should then be involved in inspections and audits, informal status meetings and more formal meetings for complex issues.
- Changes in project qualifications

Final Application
A Final Application for Approval of the transportation system must be prepared by the Safety Manager and directed to the Railway Inspectorate. The Application must include:

- Safety Report proving that all activities described in the Safety Plan are satisfactorily performed. In addition, demonstration that all issues and recommendations from Risk Analysis and Hazard Log are satisfactorily handled.
- Description of the commissioned system
- Overview of deviations from standards and relevant considerations
- Complete Risk Analysis of system
- Safety Case for signal- and communication systems according to EN 50129
- Safety Management Plan for Operational phase, including safety management systems for operation and maintenance of transportation system.

5.5 Documentation

The list below indicates the necessary document structure for demonstrating that an acceptable safety level is achieved.

Informative documents:
- Overall Concept description
- Overall scope definition description
- Hazard and risk management description
- Overall safety requirements specification
- Safety requirements allocation description

Planning documents for activities:
- Safety plan
- Verification plans
- Functional safety assessment plan
- Plan for overall operation and maintenance
- Plan for overall safety validation
- Plan for overall installation
- Plan for overall commissioning
- Plan for overall decommissioning or disposal

Reports of performed activities:
- Report from overall installation
- Report from overall commissioning
- Verification reports
- Overall safety validation report

- Overall operation and maintenance log
- Log of overall modification and retrofit requests
- Report from overall modification and retrofit impact analysis
- Log of overall modification and retrofits
- Report of overall decommissioning or disposal impact analysis
- Log of overall decommissioning or disposal)
- Functional safety assessment report

6 Safety requirements

6.1 General

For the PRT systems there should be established safety requirements in order to achieve a proper safety level according to the following method:

- Establish acceptance criteria, i.e. Quantification of objectives "Compared to similar modern transportation systems"
- "Translation" of principles into concrete requirements.

The principle is to allocate individual functions and technical systems to a designated SIL (safety integrity level). The level is decided depending upon on how critical the system is for safety. SIL level requirements are specified according to EN 50126, EN 50128, EN 50129 or IEC61508.

Additional to the above process there may exist specific safety requirements set by various authorities and clients. Further, the project developer/manager may decide on some basic safety principles for a number of reasons as the following:

- to compensate for special hazards of the system concept in relation to other transport systems
- to have a preliminary system design basis for cost estimation of the various systems,
- to be able to communicate the system safety and intended safety level to passengers and authorities. (Risk analyses results are not always easily interpretable for decision makers and authorities).

6.2 Requirements by authorities and applicable standards

The tables below indicate some safety requirements specified by regulations and guidance documents by authorities, or relevant standards as discussed in Chapter 4.

Comments have been included as notes to the tables where the requirement is of significant importance for the design of a PRT system and the understanding of the requirement is not self explanatory.

6.2.1 System safety principles, traffic control and protection

Automatic train control (ATC) system and automatic train protection (ATP) system to be designed according to a fail-safe principle.

Meaning: Separate safety system for zone control of merger of vehicles on the guideway. The safety system must be independent from the control system, i.e. separate computers, different software system, etc. The safety system must operate in case of complete failure/shut-down of the control system.

Design feature/ Safety requirement:	ASCE (US)	NFPA (US)	HMRI (UK)	BO-Strab	SJT (N)
Fool proof system safety (No human failure shall cause accidents)	X				X
Safety functions tolerant to single point failures (Shall not result in unacceptable or undesirable hazard conditions)	X				X
Software faults shall not cause an unacceptable or undesirable hazard condition	X				
Unacceptable hazards shall be eliminated by design	X				X
Automatic Train Control system fail safe design	X		X	X	
- Intrinsic fail safe design	X		X		
- Alternatives to intrinsic fail safe design	X				
- Reliable and safe communication (intrusion proof)			X		
Automatic train protection; independent of ATC	X		X		
- Separation assurance (headway)[1)]	X[2)]		X	X	X
- Un-intentional motion detection	X				
- Overspeed protection	X			X	
- Lost signal protection	X		X	X	
- Zero speed detection	X				
- Unscheduled door opening protection[3)]	X				
- Door control protection interlocks[4)]	X				
- Switch verification and interlocking[5)]	X		X	X	X

1) Either by block section (line block) principle or by moving block, e.g. the system compares the position of vehicles (trains), their direction of travel and speed to determine the safe space ahead and behind each train.
2) Separation distance based upon instantaneous stop of train ahead and sufficient distance to stop the train behind by applying emergency brakes. The stopping distance shall be calculated analytically using the cumulative "worst case" characteristics of relevant elements, where worst case pertains to the characteristic of the element that results in maximum stopping distance. This includes but is not limited to:
   - Maximum runaway acceleration
   - Minimum emergency braking condition
   - Minimum adhesion/friction
   - Maximum operating load
   - Grade
   - Maximum design tailwind
   - Maximum attainable overspeed
3) Removes traction and stops the car if doors are emergency opened while vehicle is moving
4) Interlocks against application of traction until all doors are properly closed and locked
5) The vehicle device for route selection in switches should be locked and verified locked at such a distance before a diverging switch that the vehicle can be emergency braked before entering the diverge position.

6.2.2 Guideway (elevated and general)

Structural design of the guideway should be done according to recognised structural codes and standards for the relevant country. For Norway this would be Norsk Standard NS 3420 or Eurocode (EN 1990 & 1991 a.o.).

The specified requirements are for a general and elevated guideway. Additional requirements will exist and have to be implemented for a guideway in tunnel.

Design feature/ Safety requirement:	**ASCE (US)**	**NFPA (US)**	**HMRI (UK)**	**BO-Strab**	**SJT (N)**
Loads etc for structural design	X				NS/Euro-code
- Structural support designed against highway vehicle collision	X		X	X	
Intrusion protection and detection	X		X	X	
Emergency evacuation and access[6)]	NFPA-130	X		X	X[8)]
- Safety area and walkway[7)]		X	X	X	X[8)]
Guideway alignment	X			X	X
Infrastructure/vehicle clearances	X		X	X	
Vehicle accident containment (derailment/collision)[9)]	9)		X		
Fire protection[10)]	X	X	X	X	
Signage (location identification)	X		X		
Communications	X	X	X	X	
Electromagnetic interference			X		

6) The system must have measures to evacuate passengers from stranded vehicles from every part of the guideway within reasonable time (ASCE/NFPA: 15 min) in case of vehicle breakdown or complete system failure (e.g. power shutdown)
7) In order to fulfil the criteria for evacuation, and for providing safe access for track maintenance staff most codes and standards specifies a continuous walkway or safety area along the track, but BO-Strab and ASCE/NFPA opens for alternative means to ensure evacuation at all positions.
8) The SJT regulation in Norway has a specific requirement for space to allow evacuation of trains on bridges, further it is specified that walkways along bridges should have railing, but not a requirement for a mandatory walkway.
9) Traditional railway standards have requirement for guide rails along bridges in order to constrain the possible movement of a derailed vehicle so it does not fall down from the bridge or embankment in case of derailment. This is clearly specified in the HMRI guidance on infrastructure. A vehicle containment requirement in case of derailment or collision (front-tail, front-side or side-side) should also be considered implemented for the PRT-guideway and could be implied by the requirement for "Elimination by design of known hazards"
10) Fire prevention and fire protection measures are only specified for a guideway in tunnels.

6.2.3 Stations and platforms

Structural design of the stations should be done according to recognised structural codes and standards for the relevant country. For Norway this would be Norsk Standard NS 3420 or Eurocode (EN 1990 & 1991 a.o.).

Additional requirements may exist and have to be implemented for a guideway in tunnel.

Design feature/ Safety requirement:	ASCE (US)	NFPA (US)	HMRI (UK)	BO-Strab	SJT (N)
General access and egress		X	X	X	
Emergency exits		NFPA 101			
Disabled persons access requirements	X				X
- Maximum vehicle-platform gap	X		X		
- Detectable edge warning strip	X		X		
Platform/vehicle clearances (minimum gap)			X	X	
Platform edge protection[11)]	X[11)]		X	X[11)]	
- Intrusion prevention	X[11)]			X[11)]	
- Intrusion control	X[12)]			X[12)]	
- Intrusion detection	X[13)]			X[13)]	
Vehicle arrival audio and visual warning system	X				
Platform sloping (away from track)			X		
Evacuation of misaligned trains	X				
Surveillance/CCTV	Part 1[14)]				
Audio communication	Part 1[14)]	X	X	X	
- PA-system	Part 1[14)]			X	
- Emergency call points	Part 1[14)]	X			
Emergency lighting and ventilation	NFPA-130	X	X	X	
Fire protection/prevention	NFPA-130	X	X		
- Fire detection	X				
- Fire separation	NFPA-130	X			

11) Various levels of platform edge protection are acceptable according to the ASCE-APM standards as well as BO-Strab. The highest level of protection is a full enclosure of platform with full height platform screen door. This is named *intrusion prevention* by ASCE.
12) The next level of protection is *intrusion control* barriers of minimum 1.1 m and horizontal sliding doors or gates to provide access to vehicles.
13) The weakest level of protection is an *intrusion detection* system either combined with barrier with permanent opening for vehicle doors. Intrusion detectors activating alarms and/or vehicle emergency stop, have to be installed along all opening towards the track. An *intrusion detection* system alone is not sufficient where there is risk of falling more than 1.5 m from the platform edge.
14) The requirement for audio and visual communication is handled in Part 1

6.2.4 Vehicles, traction and braking

For structural design of vehicles, crashworthiness, material selection for fire protection as well as window glazing requirements a further look at standards issued by SAE (Society of Automotive Engineers) could be warranted. Some are referenced by the ASCE-standard.

Design feature/ Safety requirement:	ASCE (US)	NFPA (US)	HMRI (UK)	BO-Strab	SJT (N)
Vehicle capacity and load[15)]	X		X	X	
Vehicle dynamic envelope	X		X	X	
Clearances towards platforms	X				
Vehicle structural design	X		X	X	
- Design loads	X				
- Crashworthiness	X[16)]		X[16)]		X
- Equipment attachment and failure			X[16)]		
Suspension and guidance	X	X	X	X	
Passenger comfort	X		X		
- Heating, Ventilation and AC	ASHRAE	X	X		
- Ride quality/ Maximum acceleration and jerk	X[17)]				
Communication systems	Part 1[14)]		X	X	
- PA-system	Part 1[14)]		X	X	
- Two-way vehicle-control room communication	Part 1[14)]		X	X	
Doors, access and egress	X		X		
- Door locking and interlocking	X	X	X	X	
- Obstruction detection & squeeze protection	X		X	X	
- Emergency egress	X	X	X	X	
Windows glazing requirement	ANSI/SAE		X	X	
Fire protection and flammability	NFPA-130	X	X	X	
- Material selection	NFPA-130[18)]	X[18)]	X	X	
- Fire extinguishers	X	X	X		
Lighting	X		X	X	
- Emergency lighting	X	X	X	X	
Electrical systems	X	X	X		
- Emergency power/batteries	X	X			
- Grounding	X		X		
- Electromagnetic interference			X		
Propulsion and braking	X	X	X	X	
- Service braking	X		X	X	
- Emergency braking	X		X	X	
- Parking braking	X		X	X	
Brake fail safe design[19)]	X		X	X	X
- Supervision of brake commands				X	
PBS Component design	X				
Controls and interlocks	X				
Verification and interlocking of vehicle switch status	Part 1 5.1.14[5)]				

15) All standards and regulations specify that car live loads shall be determined based on "crush" loading where all available car floor not occupied by seats are utilised for standing passengers. This must be avoidable for a PRT system where the interior height is not sufficient for standees and the vehicle is weighted before departure.
16) The requirement for crashworthiness of vehicle is rather weak in the ASCE APM-standard with a collision speed of 5km/h only. The requirement in the HMRI guidance on trains seems more appropriate and reads as follows: *"Passenger and train crew areas should be designed to provide a safe space for occupants under normal operating conditions and protection in the event of an accident. In the event of an accident, structural components should not intrude into areas where there are people".* Crashworthiness of equipment attachment should be considered.
17) The following values for max acceleration and jerk is specified for seated passengers:
    - Lateral & vertical acceleration: +/- 0.25 g
    - Longitudinal normal acceleration: +/- 0.35 g (including effect of grade)
    - Longitudinal emergency: +/- 0.6 g (including effect of grade)
    - Maximum jerk rate: 0.25 g/s
18) The ASCE makes reference to the NFPA-130 which specifies material testing requirements according to ASTM for the various interior components. The specification is equivalent to standards for public buses, and is considered relevant. However, only specifying fire test criteria according to US-standards may be cost driving, and further research should be done in relation to this matter. BS, DIN or EN norms should be looked for.
19) Normal requirement could be that emergency brakes are of a spring activated type hydraulic type.

6.3 Recommendations on safety requirements

Final safety requirements for an area specific PRT-system must be based on a hazard analysis and risk assessment program as specified in Chapter 5 of this document.

For preliminary planning and design the ASCE Standard Automated People Mover standards Part 1-3 (APM-standard) should be taken as a basis as it covers most aspects of a PRT system.

On some important issues the APM-standards and referenced standards (NFPA-130) are open for alternative solutions, e.g. on platform edge protection and evacuation requirements along guideway.

The following solutions could be considered for these items:

Platform edge protection: Intrusion prevention and intrusion control systems (platform screen doors or gates) is utilised for the most heavily occupied stations, whereas intrusion detection systems may be sufficient for the more lightly used stations.

Evacuation and walkway along track: Alternative evacuation means will be utilised where the track is accessible for external assistance. Where this is not possible a walkway or special emergency access or egress arrangement should be considered, e.g. across heavily utilised highways or railways.

Evacuation in fire situations: In case of fire or other emergency, the vehicle could on demand of passengers be brought to a stop within the next station or at a special emergency evacuation platform within a maximum time e.g. 30 s.

Further, we would suggest that the following safety requirements, which are stronger than similar requirements in the APM-standard, are considered as a basis for further design as they could reduce the required safety integrity level of the control system:

1) Crashworthiness of vehicles: The passenger space of any of the vehicle should not be significantly deformed by a collision between a standing vehicle and a vehicle moving at design speed, (i.e. collision load should be absorbed in bumpers at the front or rear of the vehicles as well as in corner extremities).
2) Collision between vehicles or derailment of a vehicle shall not lead to the vehicle falling down of a highly elevated guideway i.e. the vehicle and guideway must be designed so that the vehicle(s) is (are) maintained on or near the guideway in case of derailment and collisions.

One could also consider applying more sophisticated criteria for calculation of minimum allowable separation distance. ASCE specifies a procedure based on using the cumulative "worst case" characteristics of all relevant elements, where worst case pertains to the characteristic of the element that results in maximum stopping distance.

The method and criteria to be used for calculation of the stopping distance could be more sophisticated and probabilistic instead of adding on the cumulative worst case scenario.

Appendix 1: Table of Relevant statistics:

Table 1 Fatality statistics for different transport systems (Norway 1988-93)

	Average yearly fatalities	Fatalities per 10^9 person km
Private cars	183,2	4,6
Pedestrians	58,0	39,5
Motorcycles	35,3	48,9
Other vehicles	25,5	2,9
Bike	20,5	17,3
Domestic flights	7,3	1,3
Bus and taxi	4,5	1,2
Trains	2,2	0,9

Table 2. Transit Safety (Per 10,000 Vehicle Revenue Kilometers)

System	Incidents	Injuries	Fatalities
Vancouver SkyTrain[1]	0.028	0.000	0.000[2]
Lille VAL[3]	0.028	0.000	0.000
LRT Systems[4]	0.393	0.305	0.001
RRT Systems[4]	0.124	0.110	0.001

Note: [1] Based on the operating statistics in 1986/87 (EcoPlan 1990a)

[2] One woman fell between cars (7/88), and one person killed before SkyTrain was opened for service

[3] Based on the operating statistics in 1989 (EcoPlan 1990b)

[4] Statistics for RRT and LRT systems were obtained in Shen et al (1995)

Appendix 2: Rules and regulations

1. Railway Safety Principles and Guidance; Health and Safety Executive, HM Railway Inspectorate (UK)

The Railway Inspectorate in UK has issued a set of documents giving safety principles and guidance for railway systems. The publication is intended to give guidance and advice to those involved in the design and construction of new and altered works, plant and equipment affecting the safety of railways, tramways or other guided transport systems.

The document is not intended to set out mandatory standards. It describes the aspect of safety which HM Railway Inspectorate of the Health and Safety Executive would expect to see considered in railway works, plant and equipment to provide an acceptable level of safety for any people affected. The document is divided into two parts, where Part 1 sets the principles and Part 2 gives guidance and advice on how these principles can be achieved. Part 2 consists of 8 separate publications addressing various issues as: infrastructure, stations, electric traction system signalling level crossings trains etc.

The scope of the document covers all types of work, plant and equipment that may be found on all guided transport systems including mainline (heavy) railways, mass transit, light rail, tramway and heritage systems.

The principles are intended to apply to funiculars and other guided transport systems only to the extent that is appropriate taking into account the special features with the system concerned may possess. By "other guided transport system" is meant a system, other than a railway or tramway, where the vehicles operating on it are guided by means external to the vehicles. It is stated that the term therefore includes monorails and airport transit systems.

The main safety principle of the documents is that the system should be safe, and in order to ensure this all intolerable risks shall be eliminated and all remaining risk have been reduced to as low as reasonable practicable (known as ALARP). Both internal and external hazards should be considered.

In considering how to implement these principles, care should be taken to:

f) identify the complete range of foreseeable hazards;
g) assess each hazard and establish its importance;
h) provide means of preventing or controlling the hazard if appropriate;
i) provide a means of mitigating the effects of the hazards in appropriate ways; and
j) provide a means of recovery from the hazard, if appropriate

Most of the principles specified are of a rather general nature and is not specific for HMRI and the UK. Some examples of the principles are:

Safety mission: *The design and construction of new and altered works, plant and equipment should, in so far as is reasonable practicable, ensure the safety of any people who may be affected.*

Protection of the railway: *The railway should be protected against unwanted intrusion and unauthorised access.*

The track: *The track should provide for the safe guidance and support of trains.*

Trains, access and egress: *Trains should have a safe means of access, egress and retention of people and goods carried.*

Trains, communications: *There should be effective means of communicating safety messages to, from and within the train.*

Altogether, there are 33 safety principles of the above type. The majority of them are more or less self evident and apply equally well to a PRT-system as a traditional rail or metro system.

The guidance documents are more specific and many of the detailed specifications are not applicable to a PRT system. However, some are very relevant as indicated below:

2. BO-Strab (Bundesordnung über den Bau und Betrieb der Strassenbahnen)

This is a federal code for trams, metro and light rail in Germany, but the code has also been applied for systems outside Germany, e.g. for the driverless Copenhagen Metro. The code is explicitly said to apply also to driverless systems. The code mentions specific requirement for driverless systems, but there is also issued a specific guideline for driverless system.

A list of guidelines to support the BO-Strab is given below:

BOKraft/BOStrab - zugehörige Richtlinien
Dienstanweisung für die Mitarbeiter von Verkehrsunternehmen (DMV), Bezug: beka Teil 1: Nichtbundeseigene Eisenbahnen – Loseblatt Teil 2: Dienstanweisung für den Fahrdienst mit Straßenbahnen (DFStrab) – Broschüre – Loseblatt Teil 3: Dienstanweisung für den Fahrdienst mit Bussen (DFBus) ersetzt die DFKraft – Broschüre – Loseblatt – Diskette Ringbuch für DMV
Richtlinien für Betriebsfahrzeuge Schiene / Straße nach der Verordnung über den Bau und Betrieb der Straßenbahnen (BOStrab) (Betriebsfahrzeugrichtlinien Schiene / Straße), Verkehrsblatt 43, 18 / 1989 (670-671)
Richtlinien für den Bau von Tunneln nach der Verordnung über den Bau und Betrieb der Straßenbahnen (BOStrab-Tunnelbaurichtlinien) Verkehrsblatt 45, 10 / 1991 (464-469)
Richtlinien für die Spurführung von Schienenbahnen nach der Verordnung über den Bau und Betrieb der Straßenbahnen (BOStrab-Spurführungs-Richtlinien - SpR), Bezug: Erich Schmidt Verlag, Berlin, Bielefeld, München
Richtlinien für die Trassierung von Bahnen nach der Verordnung über den Bau und Betrieb der Straßenbahnen (BOStrab-Trassierungsrichtlinien) Verkehrsblatt 47, 15 / 1993 (571-576)
Richtlinien für elektrische Anlagen nach der Verordnung über den Bau und Betrieb der

	Straßenbahnen (BOStrab) (E-Baurichtlinien), Verkehrsblatt 44, 17 / 1990 (550-554)
	Verordnung über den Bau und Betrieb der Straßenbahnen (Straßenbahn-Bau- und Betriebsordnung - BOStrab)
	Verordnung über den Bau und Betrieb von Kraftfahrunternehmen im Personennahverkehr (BOKraft), Bezug: beka
	Verordnung über den Betrieb von Kraftfahrunternehmen im Personennahverkehr (BOKraft), Textausgabe mir Erläuterungen, 8. Auflage, Bezug: beka
	Vorläufige Richtlinien für den Fahrbetrieb ohne Fahrzeugführer nach der Verordnung über den Bau und Betrieb der Straßenbahn (BOStrab-Richtlinien für den Fahrbetrieb ohne Fahrzeugführer)
	Vorläufige Richtlinien für den vorbeugenden Brandschutz bei Personenfahrzeugen nach der Verordnung über den Bau und Betrieb der Straßenbahnen (BOStrab) (Fahrzeug-Brandschutzrichtlinien)
	Vorläufige Richtlinien für die Bemessung des lichten Raumes von Bahnen nach der Verordnung über den Bau und den Betrieb der Straßenbahnen (BOStrab-Lichtraum-Richtlinien), Bezug: beka
	Vorläufige Richtlinien für die Bemessung und Prüfung der Bremsen von Fahrzeugen nach der Verordnung über den Bau und Betrieb der Straßenbahnen (BOStrab-Bremsenrichtlinien)

Among the specified requirements according to BO-Strab are (own translation):

§16 (9): For driverless systems the track must be made inaccessible for access and trespassing by non-authorised person, either by fencing and other arrangement.

§19 (1): At minimum one side of a track a safety space shall be available outside of the vehicle envelope for escape of passenger and as a safe refuge for persons working trackside.

§19 (8): For elevated lines special arrangement in relation to §19 (1) can be made provided the safety of passengers and staff is adequately taken care of, and their rescue can be carried out without delay.

§23 (3): For driverless operation communication arrangement must be made to allow for a direct and prioritised speech communication between passengers and a control centre.

§29 (3): Bridge supports that are located next to streets or areas worked by cars or other free moving vehicles must be dimensioned against vehicle collision or otherwise protected against vehicle collision.

§29 (4): Walkways and safety space on bridges must be provided with fence or handrail

§31 (5): Station platforms for systems with driverless operation must be equipped to protect people from moving vehicles (e.g. platform doors or object detection systems in track).

§38 (1) stk 3: Brake commands must be supervised by the control system.

§43 (5) stk 3: For driverless systems must it be ensured that the doors are closed before the vehicle can start.

§43 (6): The doors must be kept locked while the vehicle is moving, but it must be possible for passengers to open the door in an accident or emergency situation, but not if there are no safety space for evacuation at the side of the vehicle and other arrangement is made for rescueing of passengers.

§56 (3): For driverless operation and for tracks without external safety space must arrangement be made for timely evacuation and recue of passengers in vehicles stalled along the track.

3. National Fire Protection Association (US)

NFPA-130: Standard for Fixed Guideway Transit and Passenger Rail Systems. 2000 ed.

The standard covers fire protection and fire life safety issues and is applicable to any Fixed Guideway Transit and Passenger Rail system including Automated Guideway Transit. The standard is prepared by the National Fire Protection Association, Inc in the United States and is approved as an American National Standard. The NFPA standards are also frequently used outside the United States.

Among the specific requirements can be mentioned:

3-4 Elevated Guideway

3-4.5Emergency Access
Access to the trainway shall be from stations or by mobile ladder equipment from roadways adjacent to the trackway. If no adjacent or crossing roadway exist, access roads at a maximum of 2500 ft (762 m) intervals shall be required.

3-4.6 Egress for Passengers
The transit system shall incorporate a walk surface or other suitable means for passengers to evacuate a train at any point along the trainway so that they can proceed to the nearest station or other point of safety. System egress points shall be illuminated.

5.Vehicles
5-2.4: Interior Fire Propagation Resistance
Materials and finishes installed in the vehicle shall have sufficient resisanct to fire propagation in the interioe of the vehicle by an internal fire for a period consisten with the safe avacuation of a full load of passengers from the vehicle.

Table 5-2.4 contains test procedures and and minimum (fire) performance requirements for interior materials. Typical standards are ASTM E 162, ASTM E 662, ASTM C 1166 & ASTM D 3675.

5-5 Emergency Egress Facilities

5-5.1: Each vehicle shall be provided with emergency egress facilities on the sides or at the end(s).
5-5.2: A means to allow passengers to evacuate the vehicle safely to a walk surface or other suitable area shall be provided.

5-5.3: Emergency Lighting. Emergency lighting facilities shall be provided. The power for the emergency lighting shall be automatically obtained from the storage of batteries for a period of time to permit evacuation, but in no case for less than 1 hour.

5-6.2: Communications
5-6.2.2: Each automated guided transit (AGT) system vehicle shall be equipped with a communication system considering the following:
(1) A PA system where the central supervising station can make announcements to the passengers
(2) A system whereby the passengers can communicate with the central supervising station.
5-6.2.3: Unauthorized opening of doors or emergency exit facilities shall be communicated to the central supervision station.

5-6.3: Portable fire extinguishers. Each vehicle shall be equipped with a portable fire extinguisher.

5-7 Vehicle Support and Guidance system. Failure of support, guidance, or levitation system shall not result in a system that is unsafe to passengers.

Further, the vehicle section has requirements on electrical fire safety requirements, including wiring, auxiliary circuits and battery installations.

Appendix 3: Hazard identification Log

This appendix includes the hazard log of the safety issues identified during the initial concept phase of the PRT project. This hazard log should be used as when initiating the Safety Management System.

Further, this Appendix includes a mass transit generic hazard checklist.

Infrastructure issues

Subsystem/ issue	Hazard issue/ ”Failure mode”	Cause	Consequence	Potential Measures
Guideway	Structural safety	Fatigue	Structural collapse	Inspection systems
		Collision to columns or truss	Fatalities	Signs
	Maintenance			Maintenance vehicle/travelling platform Mesh on guideway
	Fire near guideway			
	Evacuation from guideway			
	Fall from guideway Electroshock	Intrusion, unauthorized personnel climbing on structures	Fatality	Access control systems
Extreme weather		Ice/Snow on guideway Wet leaves on guideway		
		Lightning		
		Heavy Wind		
		Earthquakes		

Subsystem/ issue	Hazard issue/ ”Failure mode”	Cause	Consequence	Potential Measures
Traction - Energy supply		Power failure		
	Electroshock	Cable failure,	Injuries	
Traction - LIM		LIM failure		
Traction - Switches		Switch failure		
Stations area	Evacuation from stations	Fire Sabotage Electric failures	Fatalities	Design station emergency egress Emergency lighting
	Mugging/assaults		Injuries	Surveillance systems
	Elevator/ doors		Injuries	
Stations – vehicle loading/ offloading	Fall into guideway or ground	Crowded station area	Fatality	Platform screen doors
	Foot trapped in gap	Gap between platform and vehicle	Injury	Smooth platform

Vehicles issues

Subsystem/ issue	Hazard issue/ ”Failure mode”	Cause	Consequence	Potential Measures
Deceleration/ Brakes	Uncontrolled deceleration	Manual emergency braking (Passenger observations)	Severe injuries System emergency braking	Not install manual emergency brake
	Uncontrolled deceleration - exceeding jerk	Mechanical breakdown	Severe injuries System emergency	Limit maximum deceleration. Seat belts and

Subsystem/ issue	Hazard issue/ ”Failure mode”	Cause	Consequence	Potential Measures
	limits	• Brake failure • Shaft breakdown • Steering failure	braking	air bags - may affect efficiency.
		Overload vehicle/ People standing in vehicle	Minor injuries	Weighing vehicle Signs for seating people
	System emergency braking	Vehicle breakdown, objects on guideway	Severe injuries	
Distance control	Collision	Obstruction in guideway (thrown, fallen on guideway)	Major impact to vehicle Major injuries	Obstruction detection system
		Emergency stop or breakdown of other vehicle	Major impact to vehicles Major injuries to passengers in vehicles	
		With guideway junction	Major impact to vehicles Major injuries to passengers in vehicle	
Derailment		Wheel failure/fall off		
Personnel	People falling out of vehicle	Unwanted opening of doors		Door locks
	Person feel indisposed in vehicle (heart attack, etc)		Fatalities	How to alarm rescue team? Control system detecting vehicle not emptying. Control centre alarmed if

Subsystem/ issue	Hazard issue/ ”Failure mode”	Cause	Consequence	Potential Measures
				weight doesn’t change
Fire	Fire inside vehicle	Sabotage Electrical failure	Fatalities	Smoke detector Fire extinguisher – may lead to operational problems
Climate control	Failure of climate control	Software failure Mechanical failure	Heat Uncomfortable ride Injuries if combined with delays/stops	
Doors	Door jams		Vehicle shutdown	
	Object trapped in door	“Slim item”	Injuries	
Propulsion				
Vehicle rescue				
Doors				Manual opening on stations when stopped
Evacuation	• Evacuate to guideway • Assisted evacuation			

Traffic control system

Subsystem/ issue	Hazard issue/ ”Failure mode”	Cause	Consequence	Potential Measures
Zone control system	Positioning system failure	Software failure Cabling failure Sensor failure Computer/card		

Subsystem/ issue	Hazard issue/ ”Failure mode”	Cause	Consequence	Potential Measures
		failure Power failure Procedures/Human interface failure		
	Speed control failure	See above		
Vehicle control system	Distance control system failure	See above		
Station control		See above		
Central control		See above		
Communicatio n system	Communication system failure Level 1, 2, 3	See above		
Operation of vehicles				
Signal system				
Merger into line	Vehicle merging from station colliding with vehicle on guideway	Control system failure Wrong acceleration of vehicle (failure of inverter, vehicle overload,)	Fatalities Vehicle derailment?	Separate/indepe ndent safety system for merger zone Anti-derailment system in merger zone
Diverge into station	Vehicle wrongly diverging into station – collide with vehicles on station	Switch failure Control system failure	Fatalities?	Separate/indepe ndent safety system for merger zone
Distance control				
Fail safe principle – consequences?				
Procedures				

Evacuation and Rescue Concept

Incident in vehicle - Evacuation of passenger in vehicles on guideway

Stop at nearest station/Alarm rescue team of destination

- Panic button in vehicle
- If possible to move the vehicle, even in case of fire

Assisted evacuation

- Stranded vehicle
- Power failure
- From ground – lift vehicle
- Rescue vehicle from nearest station/depot. Rescue vehicle has built-in walkway
- Inaccessible areas – provide sidewalks

Evacuation on guideway? Not wanted?

- Need to stop people from leaving the car (lock windows/doors)
- If allowed – how to protect people from falling/from traffic/from power system
- System need to be inspected before resuming operation
- Evacuation from front/end window
- Manual opening of doors in stopped mode?

EXAMPLES OF A GENERIC HAZARD CHECKLIST.

1. BASIC DESIGN DEFICIENCIES

a. Examples:
(1) Sharp corners
(2) Instability
(3) Excessive weight
(4) Inadequate clearance
(5) Lack of accessibility

b. Causes: Improper or poor design

c. Control Methods: Improve or change design

2. INHERENT HAZARDS

a. Examples:
(1) Mechanical (i.e., rotating equipment, vibration)
(2) Electrical
(3) Explosives
(4) Flammable gases or liquids
(5) Toxic substances
(6) Acceleration (flying objects)
(7) Deceleration (falling objects)
(8) Temperature

b. Cause: Integral characteristic which cannot be designed out

c. Control Methods:
(1) Safety Devices
(a) Isolation (separation)
(b) Barriers (guards)
(c) Interlocks (deactivation)
(d) Pressure release
(e) Temperature sensor (fuse)

(2) Warning Devices (Five Senses)
(a) Visual (eye) – color, shape, signs, light
(b) Auditory (hear) – bell
(c) Tactile (touch) – shape, texture
(d) Olfactory (smell)
(e) Gustatory (taste)

(3) Procedures and Training
(a) Use of safe procedures
(b) Training
(c) Backout/recovery procedures
(d) Protective equipment
(e) Emergency procedures

3. MALFUNCTIONS

a. Examples:
(1) Structural failures
(2) Mechanical malfunctions
(3) Power failures
(4) Electrical malfunctions

b. Causes:
(1) Faulty design
(2) Manufacturing defects
(3) Improper or lack of maintenance
(4) Exceeding specified limits
(5) Environmental effects

c. Control Methods: Design
(1) Fail safe design
(2) Higher safety margins (i.e., reduce stress, increase load strength, etc.)
(3) Redundant circuitry or equipment
(4) Timed replacement

d. Other Control Methods: Safety devices, Warning Devices, Procedures and Training (See Point 2.c 1-3)

4. MAINTENANCE HAZARDS

a. Examples:
(1) Improper connections
(2) Component failures
(3) Equipment damage
(4) Operational delay

b. Causes:
(1) Lack of Maintenance
(2) Improper maintenance
(3) Hazardous maintenance conditions

c. Control Methods:
(1) Design
(a) Simplified design
(b) Fail-safe design
(c) Easy access to equipment
(d) Elimination of need for special tools or equipment
(2) Safety devices
(a) Guards for moving parts
(b) Interlocks
(3) Warning devices
(a) Labels/Signs
(b) Bells
(c) Chimes
(d) Lights
(4) Procedures or Training
(a) Documentation of proper procedures
(b) Improved training courses
(c) Housekeeping

5. ENVIRONMENTAL HAZARDS

a. Examples
(1) Heat
(2) Cold
(3) Dryness
(4) Wetness
(5) Low friction (slipperiness)
(6) Glare
(7) Darkness
(8) Earthquake
(9) Gas or other toxic fumes

b. Causes
(1) Inherent
(2) Foreseen or unforeseen natural phenomena/conditions, which do or could occur.

c. Control Methods (see also 4.c)
- (1) Design
  - (a) Increased resistance to temperature changes
  - (b) Increased resistance to dryness or wetness
  - (c) Fail-safe design
- (2) Safety Devices
  - (a) Sufficient heating or cooling capability
  - (b) Adequate insulation
  - (c) Restricted access
  - (d) Temperature sensor
- (3) Warning devices
  - (a) Visual
  - (b) Auditory
  - (c) Smell
- (4) Procedures and Training
  - (a) Use of safe procedures
  - (b) Protective equipment
  - (c) Training

6. HUMAN FACTORS

a. Examples: (also see all other items)
- (1) Stress (sensory, mental, motor)
- (2) Physical surroundings (environment)
  - (a) Noise
  - (b) Illumination
  - (c) Temperature
  - (d) Energy sources
  - (e) Air and humidity
  - (f) Vibration
- (3) Errors
  - (a) Omission
  - (b) Commission
- (4) Non-recognition of hazards
- (5) Incorrect decisions
- (6) Tasks done at wrong time
- (7) Tasks not performed or incorrectly performed

b. Causes:
- (1) Inadequate attention to human design criteria
- (2) Poor location, layout of controls
- (3) Equipment complexity
- (4) Inherent hazards
- (5) Incorrect installation
- (6) Failure of warning devices
- (7) Inadequacy of procedure safeguards
  - (a) Failure to follow instructions
  - (b) Lack of knowledge of procedures
- (8) Inadequate training
- (9) Lack of improper maintenance

c. Control Methods:

(1) Design (to address items (1) – (6)

(2) Safety Devices (Redundancy)

(a) Isolation (separation)

(b) Barriers (guards)

(c) Interlocks (deactivation)

(d) Temperature sensor (fuse)

(3) Warning Devices (Five Senses) (Redundancy)

(a) Visual (eye) – color, share, signs, light

(b) Auditory (hear) – bell

(c) Tactile (touch) – shape, texture

(d) Olfactory (smell)

(e) Gustatory (taste)

(4) Procedures and Training

(a) Clear warning labels (nature of hazard, action to avoid injury, consequences)

(b) Use of complete, proper, safe procedures

(c) Adequate training (also refresher training)

(d) Backout/recovery procedures

(e) Protective equipment

(f) Emergency procedures

(g) Proper maintenance procedures

. This checklist was developed by Volpe National Transportation Systems Center using material adapted from *Product Safety Management and Engineering* by Willie Hammer, 1980.

Appendix 4: Overview of EN Standards and Norms for Railways

European Standardisation Organisation	Reference and title of the standard	Reference document
CEN	EN 12663:2000 Railway applications - Structural requirements of railway vehicle bodies	
CEN	EN 13272:2001 Railway applications - Electrical lighting for rolling-stock in public transport systems	
CENELEC	EN 50121-1:2000 Railway applications - Electromagnetic compatibility - Part 1: General	
CENELEC	EN 50121-2:2000 Railway applications - Electromagnetic compatibility - Part 2: Emission of the whole railway system to the outside world	
CENELEC	EN 50121-3-1:2000 Railway applications - Electromagnetic compatibility - Part 3-1: Rolling stock - Train and complete vehicle	
CENELEC	EN 50121-3-2:2000 Railway applications - Electromagnetic compatibility - Part 3-2: Rolling stock - Apparatus	
CENELEC	EN 50121-4:2000 Railway applications - Electromagnetic compatibility - Part 4: Emission and immunity of the signalling and telecommunications apparatus	
CENELEC	EN 50121-5:2000 Railway applications - Electromagnetic compatibility - Part 5: Emission and immunity of fixed power supply installations and apparatus	
CENELEC	EN 50122-1:1997 Railway applications - Fixed installations - Part 1: Protective provisions relating to electrical safety and earthing	
CENELEC	EN 50124-1:2001 Railway applications - Insulation coordination - Part 1: Basic requirements - Clearances and creepage distances for all electrical and electronic equipment	

CENELEC	EN 50124-2:2001 Railway applications - Insulation coordination - Part 2: Overvoltages and related protection	
CENELEC	EN 50125-1:1999 Railway applications - Environmental conditions for equipment - Part 1: Equipment on board rolling stock	
CENELEC	EN 50126:1999 Railway applications - The specification and demonstration of Reliability, Availability, Maintainability and Safety (RAMS)	
CENELEC	EN 50128: 2001 Railway applications – Communications, signalling and processing systems – Software for railway control and protection systems.	
CENELEC	prEN 50129: 1999 (draft) Railway applications – Safety related electronic systems for signalling.	
CENELEC	EN 50159-1:2001 Railway applications - Communication, signalling and processing systems - Part 1: Safety-related communication in closed transmission systems	
CENELEC	EN 50159-2:2001 Railway applications - Communication, signalling and processing systems - Part 2: Safety related communication in open transmission systems	

Appendix 5: Norwegian Railway Inspectorate

Veiledning til prosess for godkjenning av kjørevei

Utgitt av Statens Jernbanetilsyn

1 Generelt om godkjenning av kjørevei

1.1 Jernbaneloven med forskrifter

1.1.1 Krav om godkjenning

Av lov 11. juni 1993 nr. 100 om anlegg og drift av jernbane, herunder sporvei, tunnelbane og forstadsbane m.m. (jernbaneloven) § 4 tredje ledd følger at kjørevei skal være godkjent før den settes i drift. Bestemmelsen lyder:

"Kjøreveien skal være godkjent av departementet før den settes i drift."

1.1.2 Hvem godkjenner kjørevei?

Myndigheten til å godkjenne kjørevei er i lovens bestemmelse lagt til departementet, men er av departementet delegert til Statens jernbanetilsyn i forskrift 4. desember 2001 nr. 1333 om tillatelse til å drive jernbane, herunder sporvei, tunnelbane og forstadsbane m.m., samt tilgang til å trafikkere det nasjonale jernbanenettet (tillatelsesforskriften) § 1-5.
I forskrift 4. desember 2001 nr. 1334 om krav til jernbane, herunder sporvei, tunnelbane og forstadsbane m.m. (kravforskriften) § 14-1 har Statens jernbanetilsyn fastsatt følgende:

"Før kjørevei settes i ordinær drift skal den være godkjent av tilsynet."

1.1.3 Tidspunkt for godkjenning

Av jernbaneloven § 4 og kravforskriften § 14-1 følger at godkjenning skal foreligge før kjøreveien settes i ordinær drift. Med "ordinær drift" menes at kjøreveien tas i bruk til det den er tiltenkt. Normalt vil dette være kommersiell trafikkering av passasjerer og gods. Dette innebærer at det i gjeldende regelverk ikke er krav om godkjenning av prøvekjøring av en jernbanestrekning.

1.1.4 Hva skal godkjennes?

I jernbaneloven er det i § 3 bokstav a gitt følgende definisjon av kjørevei:

"kjørevei: sporanlegg med tilhørende grunn og innretninger, signal- og sikringsanlegg, strømforsyningsanlegg og kommunikasjonsanlegg;"

Definisjonen tydeliggjør at kjørevei omfatter alle installasjoner som er nødvendige for trafikkering av tog. Videre tolker Statens jernbanetilsyn ordlydens "grunn og innretninger" slik at kjøreveien omfatter over- og underganger, plattformer og grinder.

Videre heter det i kravforskriften § 14 annet ledd:

Dersom det senere foretas endring av kjøreveien, skal dette skje i henhold til anerkjente normer, og tilsynet skal informeres på forhånd. Tilsynet kan kreve at det skal søkes om ny godkjenning dersom endringen kan påvirke sikkerhet eller miljø."

Det skilles i forskriften mellom ny kjørevei og endring av eksisterende kjørevei. Ny kjørevei skal alltid godkjennes av Statens jernbanetilsyn. Grensen for hva som er ny og hva som er eksisterende kjørevei er ikke alltid lett å trekke. Et helt nytt spor i en helt ny trasé er i utgangspunktet å regne som ny kjørevei. Også en ombygging av eksisterende spor til dobbeltspor, herunder også nye kryssingsspor, anses som ny kjørevei. Nye plattformer og over/under- ganger er også ny kjørevei.

Endring av kjøreveien skal bare godkjennes dersom tilsynet krever at det skal søkes om ny godkjenning i henhold til kravforskriften § 14-1 annet ledd. Vilkåret for at tilsynet skal kunne kreve dette er at endringen kan påvirke sikkerhet eller miljø. Hvorvidt det foreligger en påvirkning av sikkerhet eller miljø må vurderes ut fra endringens art, og ikke om prosjektet er definert som investerings- eller vedlikeholdsprosjekt. Typisk vil dette kunne være endringer som påvirker kjøreveisanleggenes funksjonalitet, kvalitet og stabilitet, som for eksempel skifte av teknologi, og oppgradering til høyere aksellast. Endring av plattformer og over / under- ganger regnes også for endring av kjørevei som påvirker sikkerhet eller miljø.

Endringer som er å karakterisere som vedlikehold, for eksempel bytte av sviller eller kontaktledningsmaster, vil tilsynet normalt ikke kreve godkjenning av. Ved utbytting av større konstruksjoner, som f.eks. broer, vil krav om godkjenning fra tilsynets side være avhengig av om man benytter eksisterende eller ny teknologi. Rassikring og profilutvidelser er eksempler på prosjekter som ikke krever godkjenning av tilsynet.

1.1.5 Hvem kan søke om godkjenning ?

Det er den som er ansvarlig for utbyggingen eller endringen som skal søke om godkjenning.

Det er ikke noe krav i jernbanelovginingen at søker må ha tillatelse til å drive jernbanevirksomhet. Spesielt for nyanlegg kan det være et annet selskap enn det som skal drifte kjøreveien som står for selve utbyggingen. Flere av de krav som gjelder kjøreveien er imidlertid knyttet opp til drift og vedlikehold, så tilsynet ser det som en fordel at det er den som skal drifte som også står ansvarlig for utbyggingen. Uansett bør de være sterkt involvert i prosessen. Når det gjelder endring av eksisterende kjørevei, vil det vanligvis være den som drifter anlegget som også søker om evt. godkjenning av endringen

1.1.6 Vilkår for godkjenning

Statens jernbanetilsyn har i kravforskriften § 14-3 og § 14-4 angitt de materielle vilkårene for at kjøreveien skal godkjennes. Disse er i § 14-3 utformet som generelle krav til kjøreveien og i § 14-4 som tekniske krav til kjøreveien, og er svært generelle. Da denne veiledningen gjelder prosessen for godkjenning av kjørevei, behandles ikke disse vilkårene nærmere her. Det er derimot en målsetting at prosessen som er beskrevet i denne veiledningen skal gjøre det enklere for søker å synliggjøre at kravene i forskriften er tilfredsstilt.

1.1.7 Hva omfatter godkjenningen?

Godkjenningen Statens jernbanetilsyn gir innebærer at tilsynet har vurdert at krav til kjørevei som følger av kravforskriften er tilfredsstilt.

Kravforskriften § 14 1. ledd lyder:
"Godkjenningen omfatter ikke forhold som reguleres av andre myndigheter".
Dette gjelder blant annet strømforsyningsanlegg (inkludert selve kontaktledningsanlegget) som hører inn under Direktoratet for brann- og el-sikkerhet (DBE) sitt ansvarsområde, og frekvens og sendestyrke på radioutstyr som hører inn under Post- og teletilsynet (PT) sitt ansvarsområde. Tilsynets godkjenning innebærer derfor ingen sluttgodkjenning av kjørevegsanlegget fordi andre myndigheter kan ha stilt krav til slike anlegg som ikke omfattes av jernbanelovgivningen. Det er videre søkers ansvar å sørge for at slike andre krav er tilfredsstilt samt at eventuelle godkjenninger og tillatelser fra andre myndigheter er innhentet.

1.2 Uavhengige sikkerhetsvurderinger

I § 14-2 annet ledd i kravforskriften har tilsynet forskriftsfestet en adgang for tilsynet til å kreve en tredjepartsvurdering. Bestemmelsen lyder:

"Tilsynet kan kreve at søker får utført en uavhengig sikkerhetsvurdering av den kjørevei, inklusive kontroll- og vedlikeholdsrutiner, som det søkes om godkjenning for."

Uavhengige sikkerhetsvurderinger kan utføres på mange forskjellige måter, og på forskjellige nivåer. Det er vanlig å benytte uavhengige parter til granskninger (av dokumenter eller produkter) og evalueringer (det som på engelsk kalles "assessment"). Bruk av uavhengige institusjoner vil som regel initieres fra utbygger selv, men i spesielle tilfelle kan det være aktuelt å gi pålegg om dette fra tilsynets side, særlig når det gjelder forhold av stor sikkerhetsmessig betydning.

I en del tilfelle, særlig ved innføring av ny teknologi, vil tilsynet be om at det engasjeres en assessor.

En assessors oppgave er å evaluere om de som har spesifisert og validert systemet har oppnådd et produkt som møter de gitte krav, at produktet er tilstrekkelig gransket og testet, og bedømme om produktet oppfyller sin hensikt. Man kan si at assessor skal ha et "myndighetsblikk" på prosessen. Nettopp av den grunn vil tilsynet som regel be om direkte kontakt med assessor.

Ved bruk av uavhengige parter reiser ofte spørsmålet om habilitet seg. Generelt blir dette et problem siden behovet for faglig tyngde er stort, samtidig som fagmiljøet er lite. Disse problemstillingene må vurderes nøye hver gang en gransker eller en assessor leies inn.

1.3 Bruk av normer og standarder

Kravforskriften § 14-3 annet ledd fastslår at:

"Kjørevei skal bygges og vedlikeholdes i henhold til nasjonale og internasjonale standarder. De standarder som legges til grunn skal være akseptert av tilsynet. Tekniske og driftsmessige minimumskrav til prosjektering, bygging og vedlikehold av jernbaner og linjeomlegginger må overholdes."

Utvalget av normer og standarder er meget stort, og det er viktig at standarder benyttes på en helhetlig måte. Ved vurdering av om standarder skal aksepteres, vil derfor tilsynet både vurdere enkelte standarder og den helhet de valgte standarder til sammen danner. Utvalgskriteriene for standarder vil også bli vurdert.
Det vil være en stor fordel om de standarder som benyttes er velkjente og bredt akseptert, bl.a. i våre naboland. Tilsynet vil foretrekke at europanormene i NS EN seriene og NEK EN seriene benyttes framfor mindre kjente standarder. Spesielt er det ønskelig at normen NEK EN 50126 benyttes for flest mulig jernbaneanlegg, og at normene NEK EN 50128 og 50129 benyttes ved anskaffelser av signalanlegg. Øvrige normer utarbeidet av TC9 i Cenelec og TC 256 i CEN anbefales også benyttet i størst mulig grad.

Forøvrig aksepterer tilsynet Jernbaneverkets JD 500 serie i gjeldende utgave som en type norm som kan brukes som en nasjonal standard.

Oppfyllelse av krav i standardene må likevel ikke anses som automatisk tilstrekkelig for godkjenning, siden det alltid vil kunne være særskilte forhold knyttet til det enkelte prosjekt som fører til at andre eller strengere krav må stilles. Disse må vurderes separat.

2 Prosess for godkjenning av kjørevei fram til søknad

Forskriftsverket gir ingen nærmere føringer for hvordan en godkjenningsprosess skal gjennomføres eller hvilke krav til framleggelse av dokumentasjon som skal stilles. Når det gjelder endring av kjørevei er det fastslått at tilsynet skal informeres. Når og hvordan er ikke beskrevet. Da tilsynet på bakgrunn av den informasjonen skal beslutte om endringen krever godkjenning fra tilsynets side eller ikke, forutsettes det at informasjonen må være tilstrekkelig for dette formålet.

I praksis har det vist seg at det er hensiktsmessig at Jernbanetilsynet involveres tidlig i planprosessen. Ved en slik tidlig involvering er erfaringen at tilsynets totale behov for dokumentasjon reduseres, og saksbehandlingstiden kan forkortes betydelig. Videre vil tilsynets eventuelle kommentarer til utformingen av kjøreveien kunne komme i en tidlig planfase der kostnadene ved implementering vil være lavere enn i senere faser. For å få til dette har man kommet til at det er hensiktsmessig at det for alle prosjekter utarbeides en ”melding om kjøreveisprosjekt” med et klart definert innhold. Denne dekker også tilsynets behov for informasjon rundt endringer på kjørevei. Videre vil det være hensiktsmessig med en dialog underveis i prosjektet basert på befaringer, møter og tilsynsaktiviteter.

2.1 Melding om kjøreveisprosjekt

Melding om kjøreveisprosjekt sendes tilsynet i en planfase der det fortsatt foreligger alternativer slik at tilsynets eventuelle kommentarer kan tas med i vurderingen av det enkelte alternativ. For prosjekter der det utarbeides reguleringsplaner bør dette skje før planen er ferdigstilt slik at tilsynet bl.a. kan vurdere trasévalg. Dette innebærer også at tilsynet på et tidlig tidspunkt har mulighet til å tilkjennegi om et eller flere alternativ ikke tilfredstiller kravene til godkjenning. Hvis det er tvil om hva som er det gunstigste tidspunktet, kan Statens Jernbanetilsyn kontaktes.

En komplett melding inneholder som minimum:

- Kontaktperson
- Fremdriftsplan
- Prosjektbeskrivelse
- Oversikt over normer og standarder
- Beskrivelse av sikkerhetsstyring
- Sikkerhetsplan
- Sikkerhetsvurdering

Hva disse punktene skal innholde for at en melding skal være komplett er beskrevet i pkt. 2.1.1 til 2.1.7. Meldingen dekker også informasjon om endring av kjørevei som er beskrevet i innledningsvis under pkt. 2.

Det er ikke nødvendig at hele meldingen er komplett før den sendes, men uten komplett melding kan ikke tilsynet ta stilling til om en endring vil kreve godkjenning eller ikke. Det er derfor viktig at meldingen kompletteres så raskt som mulig.

2.1.1 Kontaktperson

Det er opp til det enkelte foretak å avgjøre hvem som skal stå som kontaktperson, men siden hensikten er å oppnå effektiv og koordinert informasjon mellom foretaket og tilsynet, må det være en som har god kjennskap til prosjektet.

2.1.2 Fremdriftsplan

Hensikten med fremdriftsplanen er først og fremst at tilsynet skal kunne planlegge sin egen ressursbruk. Den trenger derfor ikke være spesielt detaljert på dette tidspunktet. Vesentlige endringer i fremdriften, evt. stans av prosjektet bør meldes tilsynet snarest.

2.1.3 Prosjektbeskrivelse

Prosjektbeskrivelsen vil naturlig være et plandokument som inneholder beskrivelser av de ulike alternativene som foreligger for prosjektet. Tilsynet vil eventuelt gi kommentarer til dette.

2.1.4 Oversikt over normer og standarder

En liste over normer og standarder som er planlagt brukt på et så tidlig stadium, vil nødvendigvis måtte være et levende dokument. Det bør også tas med hvordan man har valgt disse standardene, og hvordan kompletterende standarder tenkes valgt. Standardene skal ikke sendes tilsynet. Tilsynet vil be om å få oversendt standarder ved behov.

2.1.5 Beskrivelse av sikkerhetsstyring

Dette er en oversikt over hvordan sikkerheten styres i prosjektet. Beskrivelsen skal vise hvordan øverste ledelse har tilgang på nødvendig sikkerhetsfaglig kompetanse til å påse at sikkerhetsrelaterte forhold blir ivaretatt og gitt nødvendig prioritet. Likeledes må det fremgå hvordan dette arbeidet er organisert i hele prosjektet, samt hvordan krav til sikkerhetsfaglig kompetanse i stillinger med sikkerhetsfaglig betydning ivaretas. Hvordan sikkerhetsfaglig vurdering av avvik og endringer ivaretas på et tilstrekkelig høyt nivå i prosjektet skal beskrives.

2.1.6 Sikkerhetsplan

Sikkerhetsplan eller sikkerhetsprogram er en viktig del av meldingen. Her skal det fremgå hvilken sikkerhetsdokumentasjon som er planlagt utarbeidet, og hvilke sikkerhetsaktiviteter som er planlagt utført. Verifiserings- og valideringsaktiviteter faller også inn under denne overskriften. Dette vil også naturlig være et levende dokument.

2.1.7 Sikkerhetsvurdering

Dette dokumentet er også kalt konseptsikkerhetsvurdering. Hensikten med en slik vurdering er todelt. Først og fremst er det viktig å gjøre sikkerhetsvurderinger før det endelige valg av løsning er tatt slik at sikkerhet blir en parameter i vurderingen. Dernest er det viktig å kunne bruke en slik vurdering til å luke ut sikkerhetsmessig uakseptable løsninger på et tidlig stadium. Hvilket nivå denne vurderingen skal ligge på, er opp til den enkelte utbygger. Analysen skal måle sikkerhetsnivået opp mot etablerte akseptkriterier og bidra til at disse overholdes. Det må sikres at forutsetninger og begrensninger fra denne analysen blir dokumentert og fulgt opp videre i utviklingen (ref. kap. 3.2.4).

Grovanalyse (preliminary hazard analysis) er mye benyttet i tidlig fase. I forhold til endringer brukes også endringsanalyser (også betegnet som ”HUL-analyser”). Tilsynet har erfaring av at HUL analyser kan være vanskelige å tolke, siden små og store risikoforhold settes opp side ved side, og det kan være vanskelig å vurdere endringen i total risiko.

Ved endring av kjørevei legger tilsynet stor vekt på sikkerhetsvurderingen når det skal besluttes om prosjektet vil kreve godkjenning fra tilsynet eller ikke.

2.2 Endelig prosjektbeskrivelse

Når valg av løsning er foretatt, sendes det endelige plandokumentet til tilsynet.

2.3 Aksept av standarder

Hvis det er endringer i standardlisten skal den oversendes tilsynet for aksept. System for valg av standarder skal også beskrives hvis dette ikke er gjort tidligere.

2.4 Vurdering av om godkjennelse av endringer skal kreves

På bakgrunn av endelig plandokument, sikkerhetsvurdering og oversikt over standarder vil tilsynet ta stilling til om prosjektet krever godkjenning av tilsynet.
Hvis tilsynet beslutter å ikke kreve at prosjektet skal godkjennes, er videre kontakt ikke nødvendig med mindre det skjer vesentlige endringer i prosjektforutsetningene eller konseptet. Slike endringer skal evt. umiddelbart sendes tilsynet som vil vurdere om endringene er av en slik art at det vil være aktuelt å kreve at prosjektet skal godkjennes. Eksempler på endringer som må meldes er f.eks. endring i trasévalg, tilkomst til plattformer, teknologi etc.

2.5 Informasjon underveis i prosjektet

2.5.1 Melding om oppstart av prosjektering

For å komme i gang med prosessen som skal lede fram mot godkjenning er det nødvendig at tilsynet får beskjed når detaljprosjektering starter. Tilsynet vil da vurdere behovet for befaring av trasé, eventuelt krav om assessor eller tredjepartsvurdering kan komme inn her, eller senere. Det må også bli vurdert hvor tett kontakt mellom tilsynet og prosjektet som er nødvendig og ønskelig fra begge parters side. Målsetningen i denne fasen er å legge grunnlag for en god sluttdokumentasjon som kan danne grunnlag for tilsynets vurdering av om godkjenning kan gis.

2.5.2 Melding om oppstart av bygging

Når bygging starter trenger tilsynet melding om dette. I byggeperioden vil oppfølgingen ta form av møter og befaringer, og i særlige tilfelle inspeksjoner, tilsynsmøter og revisjoner. Det presiseres at nivået på oppfølgingen vil tilpasses det enkelte prosjekt, og at det i mange tilfelle vil være lite aktivitet i denne fasen.

2.5.3 Melding om faseomlegging

I mange tilfelle utføres utbyggingen i mange faser. I enkelte tilfelle, der ny kjørevei bygges ut etappevis, er det naturlig å se hver etappe for seg, og godkjenne hver etappe. Det betyr at hver etappe må ha sin komplette dokumentasjon. I andre tilfelle er fasene små og mange og tett innvevd i hverandre. Da vil separate fasegodkjenninger være uhensiktsmessig og svært ressurskrevende. I slike tilfelle ønsker tilsynet at utbygger sender en melding senest 14 dager før hver faseomlegging med en kort sikkerhetsvurdering knyttet til fasen. Særlig der faseomleggingen foregår på spor som er i drift, eller medfører at publikum må ferdes på andre områder enn tidligere, er det viktig at sikkerheten vurderes nøye. Hvis trafikken ikke påvirkes, vil en slik sikkerhetsvurdering kunne gjøres meget enkelt.

2.5.4 Melding om endringer i prosjektforutsetninger

Endringer i prosjektforutsetninger og konsept underveis skal meldes til tilsynet. Det samme gjelder hvis nye standarder som ikke er akseptert av tilsynet for det aktuelle prosjektet blir tatt i bruk.

2.6 Kontakt med tilsynet i prosjekterings- og byggefasen

Som tidligere nevnt, vil nivået på kontakten med tilsynet tilpasses det enkelte prosjekts behov, og i mange tilfelle, særlig når det gjelder endringer av eksisterende kjørevei, vil det være liten kontakt i byggefasen. Hvordan dette skal gjennomføres vil bli avtalt enten ved oppstart av prosjektering eller bygging, alt etter hva som er mest hensiktsmessig.

2.6.1 Befaringer

Tilsynet vil i mange tifelle ønske å befare den traséen som er valgt. Dette er ikke minst viktig for å danne seg et bilde av godkjenningsobjektet. Senere under byggingen vil også befaringer være nyttige, ikke minst mot slutten av byggetiden i forkant av endelig søknad.

2.6.2 Statusmøter

Statusmøter er ved siden av befaringer den mest vanlige kontaktformen underveis. I disse møtene ønsker tilsynet å bli informert om prosjektets gang. Det er naturlig å fokusere på sikkerhetsmessige utfordringer underveis, men alle typer problemstillinger kan være aktuelle å ta opp. Møtene bør ha en uformell form, og utbygger skriver kort møtereferat der det fokuseres på hva man er blitt enige om. Møtefrekvensen avtales for hvert enkelt prosjekt, og vil variere underveis.

2.6.3 Tilsynsmøter

Særlig kompliserte problemstillinger kan kreve en mer utførlig gjennomgang enn det som er vanlig i de uformelle statusmøtene. Til dette formålet kan tilsynsmøter benyttes. I forkant av disse møtene vil tilsynet som regel be om at en del dokumentasjon blir gjort tilgjengelig, og på bakgrunn av denne dokumentasjonen vil tilsynet utarbeide en spørsmålsliste som overleveres i forkant av møtet. Utbygger må da sørge for å stille med kompetanse som kan besvare de aktuelle spørsmålene. Tilsynet fører referat fra møtet. Denne arbeidsformen har vist seg svært effektiv i forhold til en rask avklaring av kompliserte spørsmål.

2.6.4 Inspeksjoner

Inspeksjoner er et verktøy som benyttes også i andre sammenhenger enn godkjenningsprosesser. Inspeksjonene ledes som regel av en av tilsynets revisjonsledere, og tar for seg en avgrenset problemstilling. Det benyttes befaring, møter og intervjuer i prosessen. Det utgis en formell rapport etter inspeksjonen.

2.6.5 Revisjoner

Revisjoner utføres i henhold til ISO 11001. De ledes alltid av en av tilsynets revisjonsledere. Revisjonens tema vil som regel være relativt bredt. Det benyttes først og fremst intervjuer som verktøy, men også befaringer kan være aktuelt. Det utgis en formell rapport etter revisjonen.

3 Søknad om godkjenning av kjørevei

3.1 Saksbehandling

Søknad om godkjenning av kjørevei sendes tilsynet pr. post. Det må påregnes minimum 4 ukers behandlingstid i tilsynet etter at komplett søknad er mottatt. Søknaden skal vise at de forutsetninger som ble lagt i forbindelse med meldingen er oppfylt. Søknaden kan være et enkelt brev vedlagt dokumentasjonen som er nevnt i pkt. 3.2 nedenfor.

3.2 Vedlegg

3.2.1 Sikkerhetsrapport

Sikkerhetsrapporten skal vise at de sikkerhetsaktiviteter som ble beskrevet i sikkerhetsplanen (sikkerhetsprogrammet) er gjennomført med tilfredstillende resultat. Den skal vise oppbyggingen av sikkerhetsorganisasjonen og gi en oversikt over utførte analyser. Alle anbefalinger fra analysene skal samles, og behandlingen av disse anbefalingene må synliggjøres. Tilsynet forventer ikke at alle anbefalinger er tatt til følge, men det må vises hvorfor de eventuelt ikke er fulgt opp, og at de er sikkerhetsmessig forsvarlig behandlet. Det samlede risikobildet sett opp mot etablerte akseptkriterier skal dokumenteres.
Det må også vises hvilke verifiserings- og valideringsaktiviteter som er gjennomført, samt resultatet av disse. Hasard log samt dokumentasjon som viser tilfredstillende lukking av relevante risikoforhold må vedlegges.

3.2.2 Beskrivelse av ferdigstilt anlegg

Beskrivelsen av det ferdigstilte anlegget skal gi en helhetlig fremstilling av anlegget som viser hvordan kravene i § 14-3 og § 14-4 i kravforskriften er ivaretatt i dette prosjektet.
Det må særlig legges vekt på grensesnitt mot tilgrensende anlegg og samspillet mellom de forskjellige komponenter i jernbanesystemet.

3.2.3 Avvik fra aksepterte normer og standarder

Listen over anvendte standarder skal nå være komplett, og alle standarder skal være akseptert av Jernbanetilsynet. Hvis det er gjort avvik fra de aksepterte standarder skal disse avvikene dokumenteres, sammen med den interne saksbehandlingen av hvert enkelt avvik.

3.2.4 Risikoanalyse

Sikkerhetsvurderingen som fulgte meldingen (ref. kap. 2.1.7) forventes å være utviklet til en komplett risikoanalyse for den aktuelle kjøreveien. Hvor omfattende den skal være, vil avhenge av prosjektets størrelse. Det er ikke gitt at analysen vil være svært omfangsrik selv om den er komplett.

3.2.5 Safety Case (signal anlegg)

For at kravene i § 14-4 bokstav k og l i kravforskriften skal kunne dokumenteres oppfylt må det for signal- og kommunikasjonsanlegg foreligge en dokumentasjon på nivå med "Safety Case" slik disse er definert i NEK EN 50129. Dette vil i praksis si at det skal foreligge både generisk og anleggsspesifikt "safety case" for alle anlegg som settes i drift. Hvis anlegget er "proven in use" dvs. anvendt så lenge i Norge at man kan dokumentere tilfredsstillende driftsikkerhet uten generisk "safety case", er det tilstrekkelig med anleggsspesifikt "safety case". Generisk "safety case" trenger ikke vedlegges så lenge det tidligere har vært vurdert av tilsynet i forbindelse med andre anlegg.

3.2.6 Assessorrapport

I de tilfelle det er benyttet assessor, jf, kapittel 1.2 foran, vil tilsynet be om at assessorrapporten vedlegges søknaden.

3.2.7 Sikkerhetsoppfølgingsplan

Sikkerhetsoppfølgingsplanen (SOP) skal vise hvilke forhold som driftsorganisasjonen må ha fokus på etter at anleggene er overtatt av dem. Sammen med vedlikeholdsplanen (skal ikke vedlegges søknaden) skal denne danne grunnlaget for sikker drift og vedlikehold av anlegget.

4 Tilsynets saksbehandling

Etter å ha mottatt søknaden vil tilsynet først ta stilling til om søknaden inneholder tilstrekkelig og komplett dokumentasjon for å kunne avgjøre om godkjenning kan gis.

Dernest vil tilsynet vurdere hvorvidt vilkårene for å få godkjenning i kravforskriften § 14-3 og § 14-4 er oppfylt.

Endelig vil tilsynet konkludere med at godkjenning gis eller ikke gis.

En godkjenning kan være avgrenset, eksempelvis geografisk, innholdsmessig eller tidsmessig. Videre kan det settes betingelser for en godkjenning, eksempelvis ved at dokumenter skal utarbeides eller aktiviteter skal gjennomføres innen en nærmere bestemt dato.

Vedtaket kan påklages til Samferdselsdepartementet. Klagefristen er 3 uker og klagen sendes Statens Jernbanetilsyn.

Appendix 6: US Federal Transit Administration; List of safety publication

Safety		Document Formats		
2002	Handbook for Transit Safety and Security Certification	PDF	HTML	Order
2000	Alertness 2000 - Tools For Managing Fatigue In Transit	PDF	HTML	Order
2000	FTA State Safety Oversight Program Annual Report for 1999	PDF	HTML	
2000	FTA State Safety Action Plan Accomplishments and the Future	PDF		Order
2000	Compliance Guidelines for States with New Starts Projects	PDF		Order
2000	Keeping Safety on Track	PDF	HTML	Order
2000	FTA Safety Action Plan	PDF	HTML	Order
2000	Hazard Analysis Guidelines for Transit Projects	PDF		Order
1997	Safety Review of Washington Metropolitan Area Transit Authority (WMATA) Metrorail Operations	PDF	HTML	Order
1996	Standardization of Availability, Location, and Use of Safety Equipment on Urban Transit Buses			Order
1996	Implementation Guidelines for State Safety Oversight of Rail Fixed Guideway Systems			Order
1994	Bus and Passenger Accident Prevention	PDF	HTML	Order
1994	Exploring How to Make System Safety Work in Transit			Order
1993	New York Metropolitan Transportation Authority Safety Investigation			Order
1989	Passenger Carrying Submersibles: System Safety Analysis			Order
1989	System Safety Planning Seminar			Order
1985	Pedestrian Falling Accidents in Transit Terminals			Order

Security			Back to Top	
2003	Public Transportation System Security and Emergency Preparedness Planning Guide	PDF	Order	Note
2002	Standard Protocols for Managing Security Incidents Involving Surface Transit Vehicles	PDF		
1998	Transit Security Handbook		Order	Note
1996	Perspectives on Transit Security in the 1990's Strategies for Success		Order	

1996	Transit Security in the 90's			Order
1996	Transit System Security Planning Seminar			Order
1993	Transit Security: Exploring New Concepts in Managing Social Problems Workshop			Order
1984	Transit Security: A Description of Problems and Countermeasures			Order
1983	Case Studies on Transit Security on Bus Systems			Order

Emergency Management

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1998	Critical Incident Management Guidelines	PDF		Order
1998	Development of a Graphics Based Automated Emergency Response System (AERS) for Rail Transit Systems			Order
1996	Crisis Intervention/Management for Transit Crews			Order
1995	Recommended Emergency Preparedness Guidelines for Urban, Rural, and Specialized Transit Systems	PDF		Order
1994	Safety Planning Information Director to Emergency Response: Resource Manual			Order
1989	Recommended Emergency Preparedness Guidelines for Elderly and Disabled Rail Transit Systems			Order
1986	Recommended Emergency Preparedness Guidelines for Rail Transit Systems	PDF	HTML	Order
1984	Evacuation and Rescue of Elderly and Disabled Passengers from Paratransit Vans and Buses			Order

Fire Safety

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1993	Recommended Fire Safety Practices for Transit Bus and Van Materials Section	PDF	Order
1992	Fire Safety Countermeasures for Urban Rail Vehicles		Order
1989	Fire Life Safety / Emergency Preparedness Planning Seminar		Order
1984	Recommended Fire Safety Practices for Rail Transit Materials Selection		Order

Accessibility

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1997	Assessment of ADA Research and Development Needs	Order
1994	Detectable Warning Surfaces: Color, Contrast, and Reflectance	Order
1994	Detectable Warnings: Detectability by Individuals with Visual Impairments, and Safety and Negotiability on Slopes for Persons with Physical Impairments	Order

1994	**Detectable Warnings: Testing and Performance Evaluation at Transit Systems**		Order
1993	**Strategies for Implementing a Standee-on-Lift Program for Fixed-Route Bus Service**		Order
1992	**Accessibility Handbook for Transit Facilities**	PDF	Order
1991	**ADA Paratransit Handbook**		Order
1987	**Tactile Warnings to Promote Safety in the Vicinity of Transit Platform Edges**		Order