INTERNATIONAL STANDARD

ISO 23019

First edition
2022-08

Railway applications — Driving simulator for drivers' training

Applications ferroviaires — Simulateur de conduite pour la formation des conducteurs

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Reference number
ISO 23019:2022(E)

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 269, *Railway applications*, Subcommittee SC 3, *Operations and services*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

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Introduction

The construction of new railway lines is carried out all over the world. For the operation of new railway lines, advanced cultivation/education of a driver's skill is necessary. Even for existing railway lines, cultivation/education of a new driver's skill and his/her sustained re-skilling are also necessary. Intrinsically, cultivation/education of vehicle crew/staff (e.g. the driver, conductor) is important to ensure safety and stability of rail transport. This is because it can bring about accident prevention and reduce the effects of abnormal working conditions (e.g. an unexpected accident, breakdown of a train and its components). Since the driving simulator can easily reproduce these abnormal working conditions, it can lead to the improvement of driving techniques and effective crew/staff training. Therefore, the introduction of the driving simulator device becomes indispensable in the field of driver training, which has very high needs and demands.

For that reason, this document has been developed to:

— define the common terminologies;

— support the creation of specifications for international procurement (e.g. to avoid the possibility of applying too many specifications that can lead to a remarkable rise in price depending on the purpose of use of the simulator);

— define what is necessary for the performance of the driving simulator depending on the training purposes to ensure that appropriate and most efficient driver training is carried out.

This document covers these needs and, as a result, contributes to the further development of the railway industry.

This document will help customers by giving them a clear vision of the minimum functions and performances required for a simulator. Thus, it can help them to define their real needs.

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Railway applications — Driving simulator for drivers' training

1 Scope

This document specifies requirements for railway driving simulators for drivers' training. It defines the minimum functions and performances for a driver training simulator.

This document is applicable to all guided transport systems, including for mainlines, metros, tramways and light rails, as part of public/private transport systems. These vehicles are intended for the operation of intercity, urban and suburban passenger or freight services with self-propelled systems and operated on either segregated or not segregated paths.

Annexes A to D provide additional information.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

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

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1 General

3.1.1
train
any guided transport vehicle that operates on tracks

Note 1 to entry: The term includes passenger trains and freight trains which vary in type (e.g. light rail, metro, mainline), speed (low speeds up to very high speeds) and distance. There can be overlapping types providing more than one function. There can exist many different compositions as appropriate (e.g. single train or multiple single trains connected together).

3.2 Actors

3.2.1
trainee
person to be trained with the driving simulator

3.2.2
instructor
trainer
person that trains *trainees* (3.2.1) with the driving simulator

3.2.3
administrator
person that manages the access, parameters and configuration of the simulator

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3.2.4
maintainer
person or company that maintains the simulator (hardware and/or software) in operational condition

3.2.5
designer
person that has the ability and the approval to create or modify the *training scenario* (3.3.2) and/or the *simulated line and environment* (3.4.4) regardless of the organization he or she belongs to

3.3 Training functions and training states

3.3.1
training mode
use of a simulator for driver training purposes

Note 1 to entry: Two training modes can be defined:

— supervised mode for a training session executed with an *instructor* (3.2.2);

— self-training mode for a training session executed alone by a *trainee* (3.2.1).

3.3.2
training scenario
simulated situation including all relevant simulated items (e.g. simulated line and environment, *simulated train* (3.4.1), *controlled train* (3.4.2)), the initial conditions necessary (e.g. choice of the line, weather, time, signalling, *simulated train* (3.4.1) initial setup, *automatic managed train* (3.4.3) position, *controlled train* (3.4.2) initial setup) and *simulated events* (3.4.5) created to specific training objective(s)

3.3.3
pause
pause of a training scenario
suspension of the real-time simulation execution by the *instructor* (3.2.2) or automatically by the simulator during its execution

Note 1 to entry: The real-time simulation execution training scenario remains paused until restarted by an action of the instructor or the system (or a trainee action).

EXAMPLE This function is to give an oral explanation by the instructor or to give a written explanation displayed to the *trainee* (3.2.1).

3.3.4
resume
resuming of a training scenario
continue the training scenario after it has been paused

Note 1 to entry: This function is available when a training scenario is paused. After an order of the *instructor* (3.2.2) or the system (or a trainee action, e.g. to close a pop up in self-training mode), the training scenario will resume at the exact location and the exact context it was at before being paused.

3.3.5
replay
playback
function that displays the *training scenario* (3.3.2) already completed by the *trainee* (3.2.1)

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3.3.6
relocation
movement of the *simulated train* (3.4.1) into another time slot or location on track inside the *training scenario* (3.3.2)

Note 1 to entry: This function is used when the *trainee* (3.2.1) has conducted a training scenario and the *instructor* (3.2.2) wishes the trainee to repeat only part of the real-time simulation (but not all the training scenario from the initial starting condition). For example, when the trainee has performed an incorrect action or had an accident, etc. and the instructor wants the trainee to quickly learn from the mistake without repeating the entire training scenario. The instructor sets the new state of the simulator from a defined condition (e.g. a recorded checkpoint position or other location or condition). Once set, the trainee is again in control of the real-time simulation and takes active control of the simulator. Data are recorded as usual.

3.3.7
training alarm
alarm or trigger that can be defined within the *training scenario* (3.3.2)

Note 1 to entry: Typically to set the limits of a normal reaction and behaviour of the *trainee* (3.2.1) (for training), there may be several levels of alarms that can activate an action in the simulation.

3.3.8
training scenario log
log of the different variables available from the simulator

Note 1 to entry: Variables can include actions made by the *trainee* (3.2.1), alarms generated by the simulator, signalling state, simulated train and safety system states, automatic and controlled trains states, instructor actions, instructor notes if available and environmental conditions.

3.3.9
assessment report
report that describes the knowledge that has been validated or not during the *training scenario* (3.3.2)

3.4 Simulated items

3.4.1
simulated train
train (3.1.1) controlled by the *trainee* (3.2.1) in the simulation

3.4.2
controlled train
train (3.1.1) that exists in the simulation but is not controlled by the *trainee* (3.2.1) (and can be controlled by the other trainees or the *instructor* (3.2.2) for a specific action or purpose)

3.4.3
automatic managed train
running *train* (3.1.1) that exists in the simulation for realism but is not controlled by the *trainee* (3.2.1), the other trainees or by orders from the *instructor* (3.2.2)

3.4.4
simulated line and environment
all the necessary parts of the guided transport system that are needed to drive the *train* (3.1.1) correctly and all the objects that are outside the guided transport system

Note 1 to entry: The term includes all guided transport system infrastructure and the outside environment.

Note 2 to entry: The guided transport system infrastructure includes:

— tracks (with their geometrical characteristics, curves, slopes and straight sections);

— power distribution systems (e.g. catenary, third rail, charging stations);

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— signalling systems used by drivers (e.g. signalling, switch and level-cross junctions (switch/point machines), passenger information equipment);

— passenger platform stations (areas visible to the driver);

— depot and stabling areas.

Note 3 to entry: The outside environment includes:

— static objects outside the guided transport system (e.g. buildings, roads, junctions, crossroads, station structures (architecture), the landscape (e.g. mountains, green areas, sea));

— dynamic objects (e.g. people (passengers and others), vehicles of all types (e.g. cars, trucks, bicycles));

— weather and time aspects.

3.4.5
simulated event
particular conditions (e.g. environmental, passenger or train behaviour, obstacles, *simulated anomaly* (3.4.6), emergencies) that are inserted into a *training scenario* (3.3.2) in order to test the reaction of a *trainee* (3.2.1)

Note 1 to entry: There are two kinds of simulated events:

— programmed simulated events that will automatically occur in a training scenario (under specific conditions defined in the software or in the training scenario script);

— free simulated events that can be inserted/deleted manually by the *instructor* (3.2.2) at any time during the running of the training scenario and activated immediately or under specific conditions (time, speed, weather or other conditions).

3.4.6
simulated anomaly
reproduction in the simulation of an abnormal item or behaviour on the transport system (e.g. a fault on a *train* (3.1.1), signal system, tracks)

3.5 Visual characteristics and functions

3.5.1
computer-generated imagery
CGI
graphical reproduction of still or animated visual contents with real-time image generating software

3.5.2
visibility
perception of the simulated items at a specified distance on the simulated line or environment typically from the driver (seated) position in the rolling stock

Note 1 to entry: The simulated items can be affected by the location of the driver (in the simulated train) on the line and can change based on the distance from the object (near or far), the perception of the driver can be affected by other simulated objects in the line of sight or due to simulated weather conditions and can change during day or night conditions.

3.5.3
clarity
clearness of the simulated items on the simulation graphical display device

3.5.4
anti-aliasing
technologies that are used to reduce the visual defects of stair-stepped on the image

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3.5.5
field of view
FOV
extent (in horizontal and vertical axis angles) of the observable world that is seen from the viewer's position

3.5.6
train field of view
train FOV
extent (in horizontal and vertical axis angles) from the driver-seated position to observe the external environment

Note 1 to entry: The train FOV defined in the train specifications usually concerns the seated driver position (focal point) to the front window edges (which defines the angles).

3.5.7
simulator field of view
simulator FOV
result of the output images generated displayed on the visual display system as observed from the driver-seated position (typically representative of the same result in the real *train* (3.1.1))

3.6 Simulator items

3.6.1
simulator failure
fault on the simulator or its equipment

Note 1 to entry: It includes failure of the computer, power failure, etc.

3.6.2
simulator log
log of events of simulator usages

Note 1 to entry: Events can include *simulator failures* (3.6.1) and simulator states

4 Conceptual considerations for simulator

4.1 General

In this clause, the whole concept and the prerequisites for developing a driving simulator for drivers' training are described, including the purpose, classification, mode and simulated guided transport system.

A driving simulator is selected according to its target use. It is therefore important to clearly define the purpose and objectives to be achieved for driver training.

This can influence both the objectives and specifications of the simulator, e.g. choosing whether to use a generic train or a specific one circulating on a generic line or a specific line for the simulation.

The driving simulator equipment has the potential to affect the health and safety of people who use it. Therefore, consideration shall be taken of the relevant and safety local rules.

Figure 1 shows a typically categorized conceptual diagram of a simulator (the type with a motion option).

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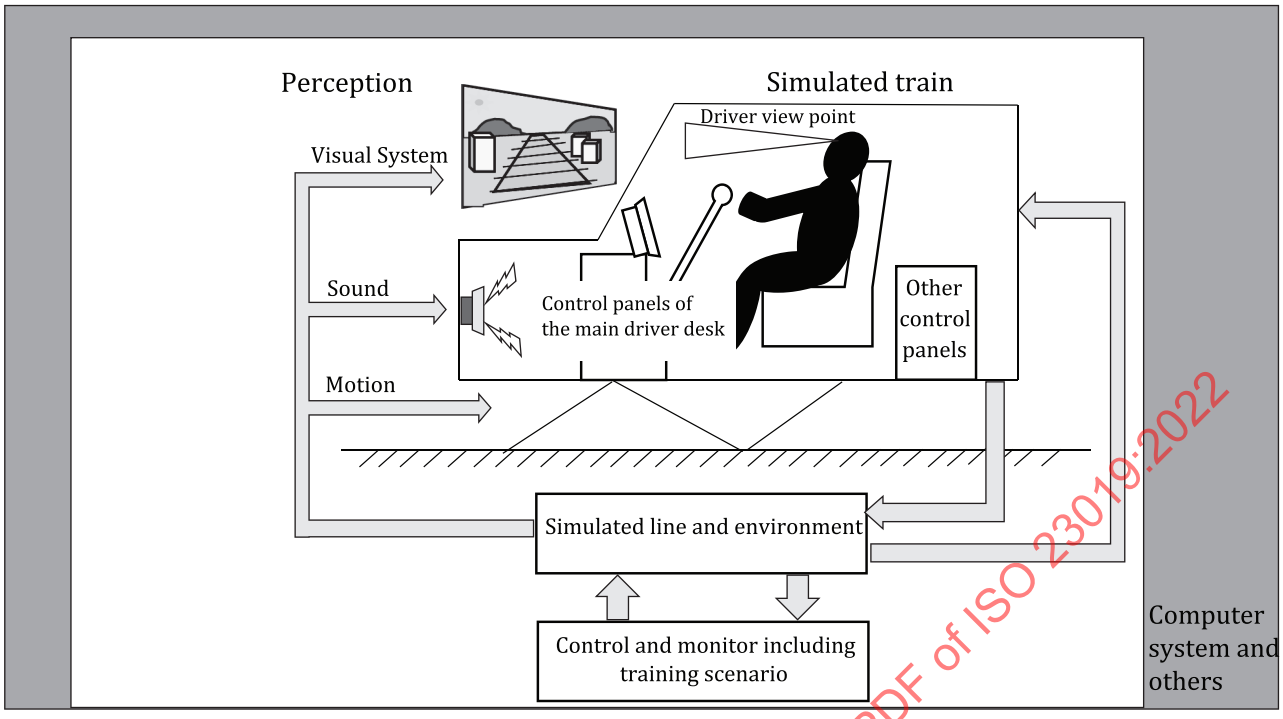

Figure 1 — Typically categorized conceptual diagram of simulator

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4.2 Purpose of simulator

The purpose(s) of the simulator for training influences the type of simulator needed. Therefore, it is important to clearly define the purpose before stipulating the specifications of the simulator.

EXAMPLE The purpose of a driver training can be as follows.

— Basic training, including:

  — train equipment operation;

  — signalling (e.g. signals rules and signal displays);

  — railway and outside environment (e.g. line knowledge).

— Advanced training, including:

  — operational rules for normal or abnormal conditions;

  — special driving condition (e.g. weather, special timetable, passenger density, vehicle simulated anomaly handling and emergencies);

  — practice driver behaviour and reactivity skills.

The use of simulators can be implemented for one instructor for one or more trainee and/or self-training (without an instructor).

NOTE The simulator also can be used for exam sessions in accordance with local regulations.

4.3 Classification of simulators

Classification of simulators is typically categorized as given in Table 1.

The types and scope of classification of simulators depend on the training purpose and budget.

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Then, Table 1 shows the typical classification of simulators as a guidance to introduce simulators. Required functions and performances of simulators are described in the Clause 5, 6, 7, 8, 9 and 10.

Table 1 — Classification of simulators

	Type 1 Replica cabin	Type 2 Full scale desktop	Type 3 Customized desktop	Type 4 Light desktop
General description	Replica of the inside of the full driver cabin structure including interior functional components as in the real train (one to one ratio replica cabin).	Reproduction of the interior functional components of the driver cabin similar to the real train (full scale and function reproduction desktop).	Physical or virtualized main driver equipment with the possibility of different arrangements to the real train, including reduction of size for the desk, equipment, cabinets, front screen (main function customized desktop).	Virtualized main control equipment. Some can be physical if necessary (main function virtualization light desktop).
Control panels of the main driver desk	Physical reproduction of all the control equipment with same spatial arrangement and same shape and size as in the real train.	Physical or virtualized reproduction of all the control equipment with similar spatial arrangement as in the real train.	Physical or virtualized control equipment with a possible compact arrangement.	Virtualized control equipment. Some can be physical if necessary. Some equipment can be shared by the same device.
Other control Panels	Physical or virtualized reproduction of all the control equipment with same spatial arrangement as in the real train.	Physical or virtualized reproduction of necessary control equipment.	If necessary, physical or virtualized reproduction of the control equipment with possible compact arrangement.	If necessary, virtualized control equipment can be shared by the same device as for the main driver desk.
Control equipment behaviour	The behaviour of control equipment reproduced in the simulator is the same as the reaction and display of the real train.	The behaviour of control equipment reproduced in the simulator is similar to the reaction and display of the real train.		
Driver external environment viewpoint	Reproduction of the cabin views of the external environment from the driver position with similar train FOV. Front external environment view is mandatory. Other views can be required as necessary.		Reproduction of the cabin views of the external environment from the driver position. Front external environment view is mandatory. Possible reduced train FOV. Other views can be required as necessary.	
External environmental effects (audio, visual, motion effects)	All necessary audio elements and effects of the simulated train and simulated line and environment			
	All necessary visual objects and effects of the simulated line and environment			
	Motion effects are possible but not mandatory (mandatory for Type 1-A)	Motion effects are possible but not mandatory (mandatory for Type 2-A)	Motion effects are possible but not mandatory (mandatory for Type 3-A)	No motion effects required
NOTE 1: Various motion systems and degrees of freedom levels are possible based on training purposes and budget. NOTE 2: If motion system is provided, an A is added to the end of the type. For example, a Type 1 simulator with motion is a Type 1-A. NOTE 3: Type 1-A, Type 2-A and Type 3-A include the specification with motion system.				

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4.4 Simulator operating modes

4.4.1 General

The operating modes define the different ways to operate a simulator.

Two different operating modes can be listed: training mode and supporting mode, as specified in Figure 2.

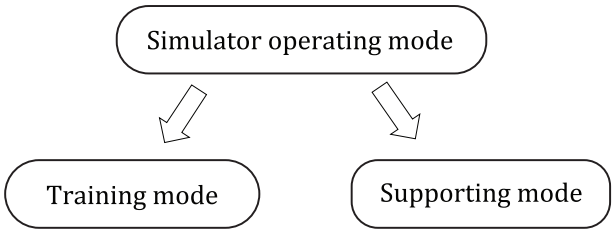

Figure 2 — Simulator operating mode

Required functions for the training mode are described in Clause 5 and required functions for the supporting mode are described in Clause 6. Common requirements for hardware and interfaces for both modes are described in Clause 7.

4.4.2 Training mode

4.4.2.1 General

Training mode is the simulator operating mode for teaching a trainee how to operate a train. The transition of states for the training mode are typically as shown in Figure 3.

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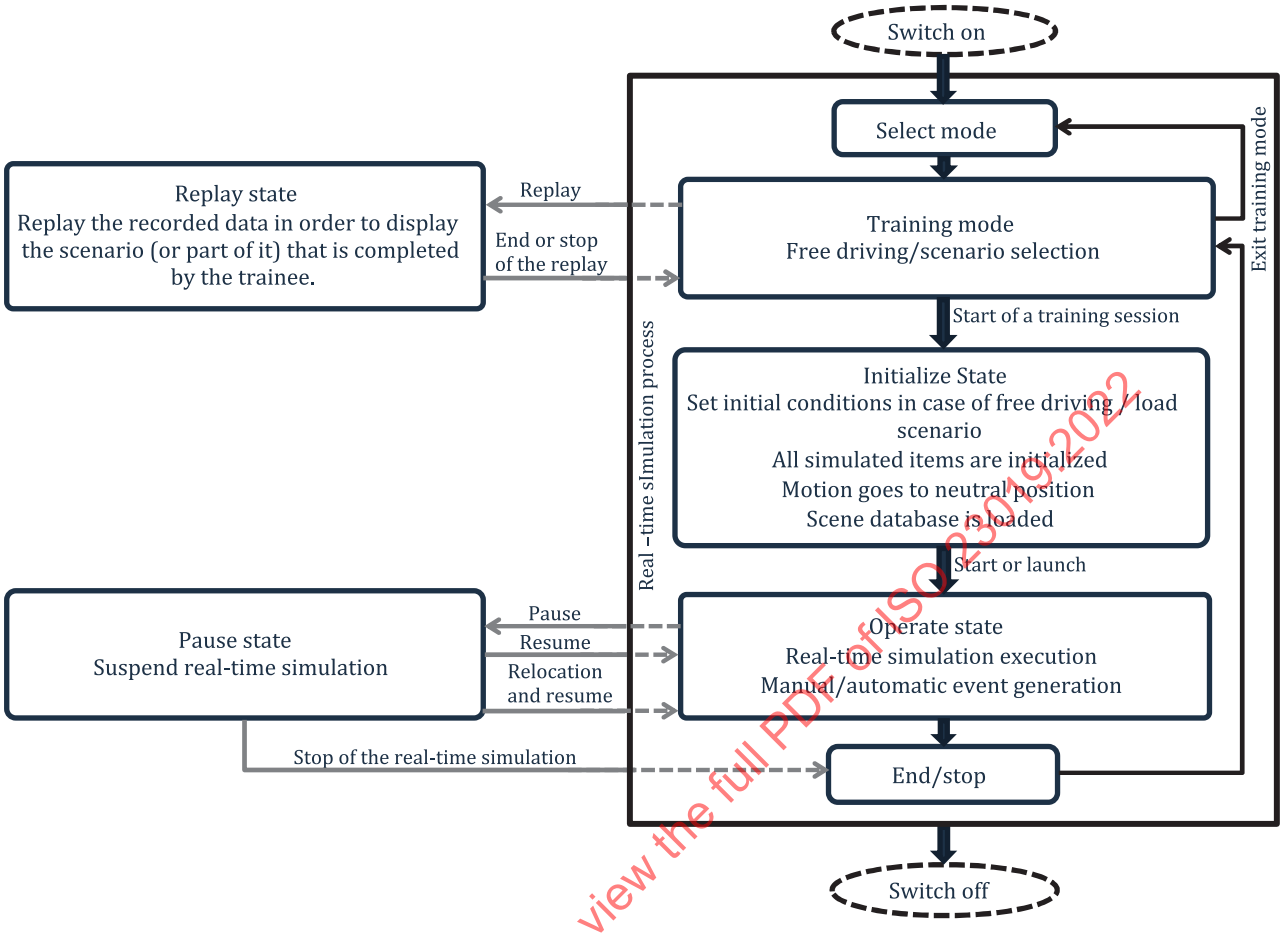

NOTE 1 Replay is independent to the real-time simulation.

NOTE 2 The neutral position of motion is the centre positions of moving range at each degree of freedom.

Figure 3 — Transition of states for the training mode

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4.4.2.2 Initialize state

The initialize state is the state in which:

— initial conditions are being set when a pre-set training scenario (free driving mode) is not used;

— the pre-set training scenario selected is loading.

At the end of the previous actions, among other things:

— all simulated items are initialized;

— motion goes to neutral position;

— the scene database is loaded.

— the simulator is ready for real-time simulation execution.

4.4.2.3 Operate state

Operate state is the state in which the real-time simulation execution with/without training scenario is conducted with a manual or automatic simulated event generation or not.

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4.4.2.4 Pause state

Pause state is the state in which the real-time simulation execution is suspended to provide instructions/change conditions or to end the real-time simulation execution.

4.4.2.5 Replay state

Replay state is the state in which the data recorded during the training session (e.g. video, sounds, simulator internal camera) are displayed offline from the real-time simulation execution (in order for the instructor and trainees to review it together).

NOTE Replay function reads and displays an output of video or data files (e.g. mp4, mpeg). Replay function can be performed on the simulator or other locations. For simulators with motion, replay cannot reproduce the movements of motion systems.

4.4.3 Supporting mode

4.4.3.1 General

Supporting mode is the simulator operating mode for the administration of the use of the simulator or for the maintenance of the simulator, as specified in Figure 4.

In this mode, the user can have access to different tools (e.g. training scenario editor, line editor).

NOTE Functions of the supporting mode are sometimes operated while the training mode is run.

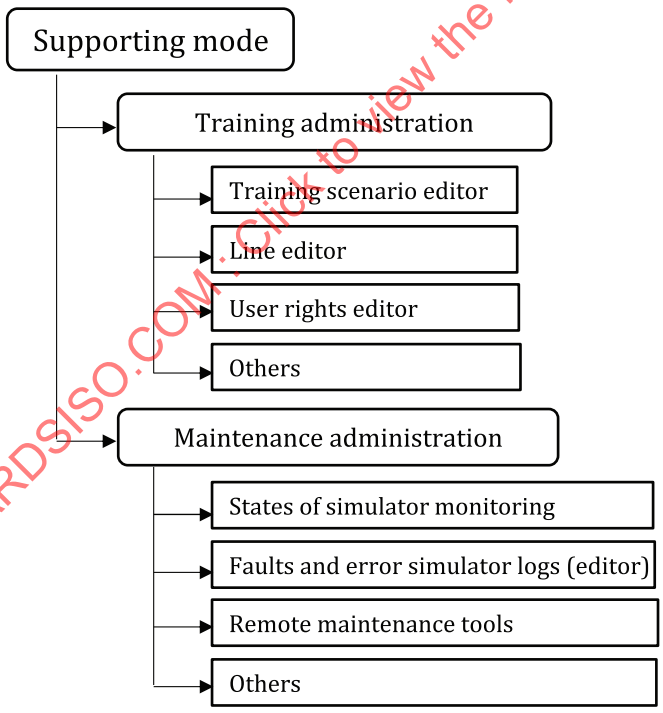

Figure 4 — Supporting mode

4.4.3.2 Training administration (training scenario editor, line editor, others)

This mode allows the designer/instructor to create or modify a training scenario or a line with relevant tools and functionalities.

It also allows them to control the access of systems and other parameters needed to manage the training.

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4.4.3.3 Maintenance administration

This mode allows the users to monitor the performance of the simulator system including the states of the simulator equipment, review simulator logs, etc.

It also allows the remote maintenance functions.

4.5 Simulated guided transport system and environment

4.5.1 General

There can be one or more types of lines modelled in the simulator as well as one or more train type defined.

4.5.2 Simulated train

4.5.2.1 General

The choice between a generic train and a specific one also impacts the training purposes and the type of simulator selected (see 4.3).

4.5.2.2 Simulated generic train

Different types of generic train with various vehicle dynamics and consoles may be provided by one simulator, with clearly defined operations to change the console and the simulated train models according to the training sessions.

The types of generic train depend on:

— the type of train to simulate (e.g. light rail, metro, mainline, freight, high speed train);

— the type of energy (e.g. electricity, diesel, hydrogen, batteries);

— the type of traction distribution (e.g. centralized/decentralized);

— the train formation (e.g. length and composition to simulate).

Adjustable characteristics of a generic train can be defined based on the purpose and given conditions, e.g. mass, traction factor, braking factor, vigilance functionality and safety features (e.g. deadman device).

The adjustment made needs to be checked that it is compatible with the real characteristics possible in the railway environment.

It is applicable, in general, for a type 2 to a type 4 simulator.

4.5.2.3 Simulated specific train

The train type and model number can be defined in order to be able to reproduce the dynamic characteristics, the subsystems, the logic, the on-board signalling, etc. of this specific train and the design of the train including the driver's cab.

4.5.3 Simulated line and environment

Three types of simulated line and environment can be defined:

— generic line and environment (creation of non-real guided transport system infrastructure and non-real outside environment);

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— geotypical line and environment (an exact reproduction of the real guided transport system infrastructure combined with a similar outside environment to the real one);

— geospecific line and environment (an exact reproduction of the real guided transport system infrastructure combined with the exact reproduction of the real outside environment).

5 Required functions and performance for training mode

5.1 General

Required functions for the training mode of the simulator can be typically categorized as follows:

— simulated guided transport system and environment;

— perception;

— control and monitor including training scenario.

The intended use of the simulators shall be specified, including the quantity and different types of simulators required, their use for training, and interactions between the instructor and trainees (connected or standalone stations). The simulator(s) training room layout shall be specified.

The following functions and performance shall be specified in order to satisfy the training purpose, required train and required environment as defined in Clause 4.

5.2 Simulated guided transport system and environment

5.2.1 Simulated train

5.2.1.1 General

In this subclause, train items which interface with the trainee and which need to be operated and recognized by a driver when running a train on a simulator are described.

This subclause describes each equipment presented physically, virtually, functionally and non-functionally.

Simulated train type (generic, specific) and scope shall be defined.

5.2.1.2 Simulated items of driver's cab

5.2.1.2.1 Minimum requirements

The contents of simulated items of a driver's cab depends on the type of simulator selected (see 4.3).

The required simulated control panels of the main driver's desk (e.g. screens, buttons, driver controllers, driving direction controllers, driver vigilance devices, obstacle detection devices) shall be defined.

Simulated control panels other than the control panels of the main driver's desk (e.g. circuit breaker panels) shall be defined.

For each of the simulated control panels of the main driver's desk and the simulated control panels other than the control panels of the main driver's desk, the method of reproduction shall be defined.

5.2.1.2.2 Best practice options

None specified.

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5.2.1.3 Simulated items out of driver's cab

5.2.1.3.1 Minimum requirements

Simulated equipment out of a driver's cab (e.g. electric cabinet, air conditioning system, train control and management system) shall be defined.

For each simulated equipment out of the cab, a simulation method (e.g. using an actual train part or using software simulation) shall be defined.

5.2.1.3.2 Best practice options

None specified.

5.2.1.4 Train running performances and behaviour

5.2.1.4.1 Minimum requirements

Train running performances and related parameters (e.g. acceleration performance, braking performance and mass) shall be defined.

Onboard control and monitor systems (e.g. train control, signalling) behaviour to be reproduced shall be defined.

The simulated train malfunctions and the way to fix them shall also be defined, as well as the safety and security onboard systems, including those connected to the signalling system.

5.2.1.4.2 Best practice options

None specified.

5.2.2 Controlled trains and automatic managed trains

5.2.2.1 Minimum requirements

As for controlled trains and automatic managed trains, the following shall be defined:

— types and performance of controlled and automatic managed trains;

— the number of trains running simultaneously;

— the way to control the controlled trains (manually or by a training scenario);

— the way to set the automatic managed trains (manually or by a training scenario).

5.2.2.2 Best practice options

None specified.

5.2.3 Simulated line and environment

5.2.3.1 General

In this subclause, the simulation of the guided transport system infrastructure (e.g. line features, tracks) and the outside environment (e.g. weather, landscape, passenger behaviour) to reproduce in the simulation is described.

Simulated line and environment type (generic, geotypical, geospecific) and scope shall be defined.

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5.2.3.2 Guided transport system infrastructure

5.2.3.2.1 Minimum requirements

The guided transport system infrastructure of a simulated line shall be defined based on the following items:

— number of stations and their type (underground/aerial, architecture aspect, number and position of platforms);

— length of the line;

— slope and curve of the line;

— tracks and switches;

— the signalling;

— power distribution systems (e.g. catenary, third rail, charging stations);

— physical interfaces (e.g. bridges, tunnels, roads, junctions and crossroads, level crossing).

The simulated signalling system shall be consistent with the real one (aspects, state, localization, interlock and the interaction with trains).

Signalling can be set during the initialize state, by loading a training scenario, by a simulated event, by the instructor's action or by other controls means.

When a specific line is simulated, the simulator requirements shall define the level of reproduction to be achieved.

5.2.3.2.2 Best practice options

Specific features should be defined (e.g. bridges, roads, junctions and crossroads, level crossings).

The clarity and the visibility should be defined (the various signals and indicators should be representative of the real driving experience).

A library of unique line objects before being instanced should be available to allow fast changes to the initial object in the modelled line.

5.2.3.3 Outside environment

5.2.3.3.1 Minimum requirements

The outside environment shall be defined based on the following items:

— weather (e.g. sun, rain, fog, snow, cloud), season and time of days;

— static objects (e.g. landscape, cities, buildings, roads, tunnels);

— dynamic (moving or animated) objects, e.g. human (with specific defined behaviours), road vehicles (for the tramway) and others (e.g. smoke, fire).

NOTE 1 Human behaviour can be normal or abnormal behaviour:

— normal behaviour: following the rules (e.g. waiting for the train passively, letting people get off the train without blocking the exit, getting on the train once everyone has gotten off the train);

— abnormal behaviour: not following the rules (e.g. blocking the door of the train, getting on the train before other passengers get off, running along the platform, crossing the tracks before the train, running toward the train, fighting).

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NOTE 2 Behaviour of road vehicles can be normal or abnormal behaviour:

— normal behaviour: following the rules (e.g. stopping at a red light, driving at the correct speed, staying in line);

— abnormal behaviour: not following the rules (e.g. driving fast, changing lines, disregarding traffic signals, crossing the tracks before the train).

In case of a generic line, the scope and contents shall be defined.

In case of a specific line, the scope, contents and level of reproduction shall be defined (geotypical or geospecific).

5.2.3.3.2 Best practice options

The number or the level of quantity (e.g. light, normal, crowed, overcrowded) of passengers observable by the driver (e.g. per station, per train and per platform) should be defined.

The number of identical or different passengers or vehicles should be specified.

If necessary (e.g. for a tramway driving simulator), the number of different types vehicles (e.g. cars, trucks, bicycles, motorbikes, planes, automatic managed trains) and the different levels of quantity of vehicles on the road or in the air (light, normal, crowded, overcrowded) should be defined.

Behaviour of passengers and vehicles should be natural (e.g. avoiding obstacles).

5.3 Perception

5.3.1 General

In this subclause, the simulation of perceived and recognized information by a driver when running a train is described.

5.3.2 Visual system

5.3.2.1 Visual image generation

5.3.2.1.1 Minimum requirements

The method for image generation shall be defined, for example:

— computer graphics;

— actual photographed images;

— video;

— other method.

The requirements for visual image generation shall be defined, including, for example, the following items:

— resolution;

— update/refresh rate (minimum 30 Hz for CGI, 25 Hz for video);

— number of output view ports;

— output video format (region example: NTCS, PAL; file format example: MP4, AVI);

— colour depth (e.g. 48 bits colour/16 bits per RGB).

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If used, computer graphic requirements shall be defined, including, for example, the following items:

— graphical performance:
  — scene generation capability (e.g. update cycle at a viewport/for each screen, number of polygons per frame to be displayed);
  — minimum resolution (e.g. full HD or 4K);
  — anti-aliasing;
  — flicker.
— graphical contents:
  — time of day (day/night/dusk);
  — weather pattern (sunny/cloudy/rain/snow/visibility);
  — outside environment objects (e.g. buildings, bridges, tunnels, roads, junctions, crossroads, level crossing, station structures (architecture), landscape (e.g. mountains, green areas, sea)) generated by 3D database models;
  — headlight effect;
  — moving objects (type, quantity, degrees of movement);
  — signals;
  — useful indication/information objects.

The visual image generation shall be representative of the conditions modelled (e.g. train speed, train stop positions, train braking, train accelerating).

The visibility and the clarity of every graphical object (e.g. signals, indication) useful for driving shall be defined.

5.3.2.1.2 Best practice options

None specified.

5.3.2.2 Visual display

5.3.2.2.1 Minimum requirements

The type of visual display shall be defined for the front, side, rear and lateral views, as appropriate.

The type of visual display may be as follows:

— projector;
— monitor (e.g. LED, OLED);
— immersive headset, head mounted display, etc.;
— other systems.

The following parameters shall be specified for each visual display:

— display size (for each type of view);
— minimum resolution;

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— refresh rate;

— colour depth.

For each view, the simulator FOV shall be defined.

The minimum view to be displayed shall be the front view.

5.3.2.2.2 Best practice options

The following view can be displayed depending on the needs:

— lateral view;

— rear view;

— carriage view;

— camera view;

— other views (e.g. external view, helicopter view).

5.3.3 Sound

5.3.3.1 Minimum requirements

When a sound function is provided, the generated sound shall be defined.

Three types of sounds can be listed:

— sounds of the simulated train:

  — sounds audible in the driver cab (e.g. driving desk logic sounds, anomalies, signalling system sounds, fire alarm);

  — sounds made by the movement of the train;

  — sounds made by the behaviour of the train (compressors, braking discharge);

  — sounds made by the different environments encountered by the train (e.g. tunnel, viaduct, crossing train horn, crossing train noise);

— the communication between the driver and other actors (e.g. conductor, instructor, passenger, traffic controller/dispatcher, operations control centre (OCC) staff, station staff);

— the public announcement inside the train or on the platform if audible from the driving cab.

The sounds to be reproduced shall be defined.

The sound system, sound channel, sound range and volume shall be defined.

The sounds and the default volume of each type of sound shall be controllable.

The sound system volume/intensity shall take into account the relevant health and safety rules.

5.3.3.2 Best practice options

The sound system volume/intensity may be adjustable.

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5.3.4 Motion

5.3.4.1 Minimum requirements

When a motion function is provided, the following items shall be defined according to the purpose of training:

— motion system (e.g. electric or hydraulic motion platform or motion seat);

— degree(s) of freedom;

— payload;

— moveable length and angles (displacements);

— velocity and acceleration;

— angular velocity and angular acceleration;

See Clause 8 for installation requirements.

It shall be possible to activate or deactivate the motion function before launching a training scenario.

It shall also be possible to deactivate the motion function when a training scenario is running.

Measures for safety shall be specified if a motion system is provided, e.g. in emergency stop locations or areas of protection.

5.3.4.2 Best practice options

None specified.

5.4 Control and monitor including training scenario

5.4.1 General

In this subclause, control and monitor including a training scenario, are described.

5.4.2 Control and monitor

5.4.2.1 Minimum requirements

Simulation control items (e.g. start/stop, initial condition set, visual control, emergency set) shall be defined, reflecting the needs of the training.

Functions for control and monitoring are categorized as follows:

a) Control and monitor for the basic operation of the simulator shall be defined, including:

— electrical start/stop control functions of the simulator;

— monitoring functions of the states of the simulator(s) (e.g. power on, power off, simulator failures, simulator logs);

— control functions of any safety features (e.g. emergency stop of motion system);

— emergency operation functions (e.g. power failure of the simulator);

— reaction of the simulator system during emergency operations to ensure protection from damage and safe operation (e.g. power failure of the simulator).

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b) Control and monitor for supporting mode shall be defined, including:

- administration of the instructors, trainees and designers (to add, modify, delete or configure the access);
- administration of the training session (e.g. defining the training scenarios of a training session, identifying the time spent on a simulation);
- administration of records (a method for the protection of personal data shall be defined);
- management of training scenarios (see 5.4.3);
- maintenance functions (see Clause 9).

c) Control and monitor for training mode shall be defined, including:

- evaluation of training (e.g. manual/automatic forms, scoring functions);
- control of the different display views for the instructor stations and observer stations.

For each training mode (supervised or self-training mode), the control and monitoring functions to be available shall be defined, as well as the type of human machine interface (HMI) (e.g. graphical HMI, mouse-controlled or tactile).

The monitor items and monitoring method shall be defined. If the monitoring parameters can be adjusted by the instructor, this shall be specified.

The on/off operation sequence of the training session shall be defined.

5.4.2.2 Best practice options

The mobility needs of the user of the control and command functions should be considered for the design of the device providing these functions.

a) Control and monitor for simulator basic operation:

- visualization of the components of each subsystem of each simulator should be provided.

b) Control and monitor for supporting mode:

- line editor management (see 6.2.3) should be provided;
- if remote control functions are required, the control actions of remote-control equipment (e.g. the start, shutdown and restart of the projector) shall be specified.

c) Control and monitor for training mode:

- if record and playback function is required, parameters (e.g. simulation logs, initial conditions, alarms, data, sound, communications) and recording length (duration in seconds, minutes or hours) shall be defined;
- additional audio-visual monitoring technology may be implemented to support driver training and evaluation (e.g. eye tracking, hand tracking, voice recording and recognition), and, if required, the creation or modification of a scoring function, configurable items and parameters shall be defined for example:
  - punctuality;
  - train stop accuracy;
  - driving smoothness;
  - speed limit compliance to operational procedures.

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The items depend on the type of simulator, on the use of an existing line/train or not and on the training scenario selected.

It may be possible for the instructor to perform the evaluation during or after the real-time simulation execution (e.g. by filling in an evaluation form during or after the real-time simulation execution). It may also be possible for the instructor after the real-time simulation execution to add manually some comments on the assessment report.

These evaluation functions may be based on graphics generated by the simulator and displaying the main simulation data according the simulated time (e.g. simulated train speed, train position, signals states, trainee actions).

Some evaluation may be performed automatically by the simulator following defined criteria.

If scoring functions are available, scoring items, criteria and the mode of scoring (manual or automatic) shall be defined.

The automatic scoring functions should be available if the technology is compatible and the instructor should be able to activate/deactivate them.

In case of automatic evaluation or scoring of the performances, the items to be evaluated or scored automatically and the criteria shall be defined.

5.4.3 Training scenario

5.4.3.1 Minimum requirements

A training scenario is made up of one or more simulated events allowing an instructor to train or/and retrain to specific learning objectives.

The training scenario requirements shall be defined (e.g. number of training scenarios, type of simulated events).

The required functions for the management of training scenarios shall also be defined.

Regarding the use of training scenarios in the simulation, the following functions shall be provided by the driving simulator:

— launch of a training scenario (launch one by one or launch by a group of simulators);

— stop of a training scenario (stop one by one or stop by a group of simulators);

— use of communications between the instructor (who is playing several roles) and the trainee.

The variables to be displayed in the training scenario log shall be defined.

5.4.3.2 Best practice options

The following functions should also be available:

— manual insertion of simulated events (without pausing or freezing a training scenario, and without alerting the trainee); the realization of the new simulated event should be carried out automatically;

— pause (one by one or by a group of simulators);

— resuming of a training scenario (one by one or by a group of simulators);

— relocation inside a training scenario (time relocation or spatial relocation, and train conditions);

— display of multimedia materials during a pause;

— activation of the motion system or not;

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— activation of a recording or a snapshot or not; the activation of a recording should include the data, sound, communication and video from the in-cab CCTV camera (if it exists, for observation of the trainee in the simulator);

— replay of a recorded training scenario;

— access to the training scenario log.

The pause, resuming and relocation functions should be available if the technology used is compatible (e.g. when the driving simulator is interfaced with a real signalling component that participates in the simulation, the pause function is not always possible due to the real equipment and its software).

If the pause function is available, after a pause, the instructor should have the ability to:

— relocate the simulated train in another time slot or location on the track inside the training scenario;

— save the execution of the training scenario;

— reset the last simulated event that paused the training scenario (e.g. major accident, obstacle);

— resume the training scenario.

After a pause by the driving simulator, it should be possible to resume the training scenario by a trainee action (e.g. close the pop up).

After having saved the execution of a training scenario, the instructor should be able to stop the training scenario and end the training session. He/she should also be able later to load the execution of the training scenario that has been saved and let the trainee get back to his/her training session at the exact moment he/she left the training scenario with the exact context.

The reset of the last simulated event should be managed only by the instructor during a supervised mode simulation. During a self-training mode simulation, it should be defined how to reset an alarm by the trainee. (It allows the trainee to continue the completion of the training scenario after having made a major driving mistake with major consequences in the simulated environment.)

If required, the time needed to launch a training scenario shall be defined.

6 Required functions and performance for supporting mode

6.1 General

In this clause, the required functions and performance for supporting mode are described (see 4.4.3).

a) Training administration:

   — training scenario editor;

   — line editor;

   — user rights editor;

   — others.

b) Maintenance administration:

   — states of simulator monitoring;

   — faults and error simulator logs (editor);

   — remote maintenance tools;

   — others.

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6.2 Training administration (training scenario editor, line editor, others)

6.2.1 General

In this subclause, requirements for tools which are built into the simulator system to create the training scenarios or the lines are described.

6.2.2 Training scenario editor

6.2.2.1 Minimum requirements

None specified.

6.2.2.2 Best practice options

A driving simulator should provide a training scenario editor. When a training scenario editor is provided, this editor should integrate the following functions:

— creation of a new training scenario (see definition above);

— renaming of a training scenario;

— duplication of a training scenario;

— modification of a training scenario;

— deletion of a training scenario;

— testing of a training scenario;

— import/export of training scenarios;

— upload/transfer of training scenarios from the training scenario editor to the simulator(s);

— saving and storage management of training scenarios.

All training scenarios should be capable to be exported in a generic format (e.g. as an XML/JSON format).

When performing a software upgrade of the simulator, the following should be considered:

— function for the export of an existing training scenario;

— assessment of the training scenario compatibility with the new software version;

— update of the training scenario as required;

— import of the training scenario of the new software.

The settings available for the creation of a training scenario (e.g. to define the narrative of the training scenario) are made up of the following:

— location settings (e.g. spatial or time location);

— variables, including relative to the train, the infrastructure, the operation (e.g. routes information, schedules information), the environment and the passengers.

A training scenario should be able to be used with or without motion.

If training alarms are available, the designer should also be able to define them inside the training scenario by using the following settings:

— the description of the training alarms;

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— the format of the training alarms (text, sound or video message);

— the conditions when the training alarms are triggered;

— the recipient of the training alarms (the trainee, the instructor or both).

The training scenario editor should have a graphical interface, with the use of the guided transport system infrastructure representation, facilitating the scenario designer to locate and identify the simulated events.

6.2.3 Line editor

6.2.3.1 Minimum requirements

None specified.

6.2.3.2 Best practice options

A simulator may include a line/environment editor function or module (as defined in the requirements specification). The line/environment editor should provide the following functions so that the user of a simulator should be able to modify the simulated environment model:

— creation of a new line and or environment;

— modification of a line and or environment;

— duplication of a line;

— rename of a line;

— deletion of a line.

The creation of a line should be based on predefined libraries of graphical objects to be assembled (e.g. tracks, landscape, building, roads, bridge, platform, signals) and on settings (e.g. slope, curve, length). The generated line should include the signalling, electrification and all features to run the corresponding train on it.

This feature should be specified when defining the initial purpose and specification of the simulator.

6.2.4 Others

6.2.4.1 Minimum requirements

None specified.

6.2.4.2 Best practice options

The management of the database including all the sounds of the simulator should be available.

For example, it should be possible for the designer to replace a sound by another one.

6.3 Maintenance administration

6.3.1 General

In this subclause, requirements for a built-in maintaining function are described.

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6.3.2 Minimum requirements

When a self-diagnosis is provided, the diagnosing items shall be defined.

When a remote maintenance system is provided, the monitoring items and remote controlling items shall be defined.

Whether to or not to implement the remote maintenance function shall be defined. If the remote maintenance is needed, what to be monitored remotely shall be defined.

6.3.3 Best practice options

Whether to or not to implement the remote maintenance function, as well as what parts to monitor remotely, should be determined in consideration of the following matters:

— response time of the maintenance organization when a product fault occurs;

— training level, maintenance skill and capability of personnel in the organization;

— sensor reliability;

— cost comparison between remote maintenance and site maintenance;

— usage (e.g. availability, time of use) forecast for the driving simulators.

To facilitate the supervising, including maintenance and monitoring, of the simulator, a centralized remote system which allows access to the software should be incorporated into the design of the simulator and made available to the maintainer. This enables the maintainer to access the operating software, from a distance portal, including the equipment and the control system in the simulator. Thus, any mechanical, electrical or technical fault of the simulator can easily be accessed and dealt with remotely by the maintainer.

This centralized system, allowing remote access to the operation/control system of the simulator, should also incorporate a built-in security system to minimize the risks of online cyber-attacks, hacking or viruses to infiltrate the software.

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7 Required functions and performance for computer system and auxiliary simulator equipment

7.1 General

In this clause, the required architecture and computer aspects are considered in order to be able to fulfil the requirements described in Clauses 5 and 6.

7.2 Computer system

7.2.1 Minimum requirements

The computers, hardware and software components of a simulator shall be compatible with the usage forecast.

NOTE 1 The time of usage (intensive use: seven days a week, ten hours per day), the data needed to be stored and external system to interface with a simulator have a major impact on the performance required for items for example:

— central processing unit (CPU) performance;

— memory size and storage capacity;

— peripheral interface;

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— operating system;

— security software and package software.

The computers and the controls belonging to the simulator system are connected by a simulator network.

The simulator network needed (isolated or not) shall be defined.

NOTE 2 The simulator network can be isolated and completely standalone or connected to a local network or connected directly to internet.

Any interface between the simulator network and any other external network shall be identified.

Hardware and/or software security requirements shall be defined.

EXAMPLE ID and password authentication (recognition), fingerprint authentication (recognition), face recognition.

7.2.2 Best practice options

The computer system should monitor the system performance (e.g. CPU performance, memory usage, data storage usage).

Cybersecurity analysis and consequent protections should be implemented if needed.

If there is remote access to the simulator or part of it, the scope of remote access shall be specified (e.g. maintenance, remote maintenance (see 6.3), remote simulator session display), as well as the functionalities that can be controlled by remote.

7.3 Interfaces

7.3.1 Internal interfaces

7.3.1.1 General

The simulator may physically consist of different stations (e.g. trainee station, instructor station, designer station, observer station) that can be separated, standalone or integrated.

7.3.1.2 Minimum requirements

None specified.

7.3.1.3 Best practice options

None specified.

7.3.2 External interfaces

7.3.2.1 General

In this subclause, the interface with external systems and equipment is described.

7.3.2.2 Minimum requirements

It can be useful to interface external systems to the driving simulator, for example:

— learning management system;

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— real railway equipment that will be part of the training (e.g. pantograph, signalling components, software);

— joint simulation training (e.g. with the dispatcher and station attendant simulation training system).

If applicable, how to interface the external systems and the data to be exchanged with the external systems shall be defined.

7.3.2.3 Best practice options

Protocols for data exchange for a learning management system should be defined (e.g. SCORM, AICC, Tin Can/xAPI).

7.4 Auxiliary simulator equipment

7.4.1 Minimum requirements

Technical data of each power supply equipment and air conditioner in the simulator shall be defined.

If there are any special equipment other than power supply equipment and air conditioner, technical data of each special equipment shall be defined.

7.4.2 Best practice options

None specified.

8 Requirements for simulator installation

8.1 General

In this clause, the requirements for simulator installation are described.

8.2 Minimum requirements

The following items shall be specified (according to the simulator type) in order to install a simulator in a facility:

— local safety and health rules;

— required space;

— mass and force to the floor;

— type and specification of the floor (e.g. real floor or fake floor), concrete and cable path;

— fixation requirements in the room and to the floor (in particular for a motion system);

— required power supply type and capacity (e.g. power, voltage, current) and architecture (internal wiring and external connections);

— amount of heat generated by the simulator equipment;

— required operating environmental conditions (e.g. ambient temperature, ambient humidity, altitude);

— required storage environmental conditions for spare parts (e.g. ambient temperature, ambient humidity, altitude);

— network connection.

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