



2TRAIN | Benchmarking Report on computer-based Railway Training in Europe

Training of Train Drivers in safety-relevant Issues with validated and integrated computer-based Technology

2TRAIN



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Editors: Marcus Schmitz (IZVW), Christian Maag (IZVW)

Authors: Marcus Schmitz (IZVW), Christian Maag (IZVW), Jakub Pechoucek (Ceske Drahy), Dusan Pouzar (Ceske Drahy), Hana Vagnerova (Ceske Drahy), Alejandro Gil (UPM), Jose Manuel Mera (UPM), Luis Miguel Gutierrez (UPM)

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Photos: IZVW (unless otherwise noted)

Contact: University of Wuerzburg, IZVW – Center for Traffic Sciences, Roentgenring 11, 97070 Wuerzburg, Germany, info@2train.eu, <http://www.2train.eu>

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Definitions

The definitions below prepare for a common understanding of constantly used terms during the course of the report. These definitions do not intend to be universally valid:

- Initial training: Training of train driver in preparation for passing the exam (other: education, apprenticeship)
 - Advanced training: Training for examined train drivers (other: continuous training, further training, ongoing training)
 - Assessment: The process of measuring the performance/competence
 - Examination: Assessment for the purpose of getting a specific (driver) licence
 - Performance Check: Assessment for the purpose of regular competence assurance (other: performance monitoring/competence assessment)
 - Evaluation: Ascertain the overall quality of the training (not the driver's performance)
 - Training objective: The specific knowledge, skill, or attitude that the trainees are to gain as a result of the training activity
 - Training content: Describes what is done in the training to reach the training objectives (other: topic)
 - Training model: Describes the circumstances of the training including the specification about the training schedule (e.g. non-recurring, monthly, once or twice a year), the overall duration of one session, the circle of addressees, the presence of an instructor, the necessity of a briefing/debriefing etc.
 - Training method: Describes how and with the aid of which means and technologies (classroom lesson, CBT/WBT, simulation, real vehicle) the training is conducted
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- Training technology: Computer-based training methods e.g. simulation, CBT/WBT, e-learning tools
 - Training tool: Add-on systems for training technologies

In combination with Simulator or Training:

- Session: A whole training unit (may include briefing, pre-test, train preparation, the actual drive, and debriefing)
 - Drive: Driving in the simulator (there may be more drives in one session)
 - Event: A specific operational or technical occurrence in the course of a drive; there could be several events in a single training drive (other: situation)
 - Scenario: the actual figuration of the drive e.g. the sequence of events, the choice of the route, specific train settings, the weather conditions etc.
 - CBT modules: Computer-based training modules
 - WBT modules: Web-based training modules
-

1. Introduction



Chapter 1

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1.1 The project 2TRAIN

The establishment of safe, competitive, and interoperable railways in Europe requires particular attention to the qualification of train drivers. As Europe grows together and cross-border operations increase there is a strong need to harmonise and coordinate the training of train drivers concerning general driving and operational abilities as well as particular crisis management competencies. In order to strengthen a European harmonisation in rail traffic it is appropriate to advance common training technology as well as common training contents. Developments concerning these two aspects are the scientific and technological objectives of 2TRAIN.

Individual European countries differ in national laws, engine technology, signalling systems, rule books, and general training structures – the report at hand gives an overview of this diversity concerning training concepts and technologies. As a consequence of the diversity,

a complete harmonisation of training technology and training contents will be unachievable. Taking into account experiences made in the past, 2TRAIN aims at developing European best-practice guidelines for an efficient, safety enhancing, and cost-effective use of modern technologies for training and for the ongoing competence and performance assessment.

Important benefits can be obtained by the use of computer-based systems and simulators in training. These computer-based technologies facilitate the establishment of common training efforts for train drivers in Europe. They also contribute to an enhancement of training efficiency by enabling interactive training of realistic situations. In contrast to training in real environment, the training session can variably be composed of different technical failures and abnormal operational situations of which many cannot be trained in reality. Furthermore, it is possible to replicate scenarios at any given time. Starting point of 2TRAIN is the benchmarking of (1) training

tools and technologies as well as (2) training contents and models already in use in different European countries. As a first step, the state of the art concerning training technology (e.g. simulator hardware, architecture, and software) and drivers' competencies and training contents was analysed by reviewing the relevant publications. The second step was the collection of data about training systems of European railway undertakings with a special focus on simulation and training contents related to driving under abnormal and degraded conditions as well as human factor contents. This step is the subject matter of the benchmarking report at hand. Based on these benchmarking results, the requirements for future computer-based training concepts will be specified in the subsequent phase of 2TRAIN, taking into account the information derived from the questionnaires and from the discussions with the representatives of the interviewed companies. Concerning the technical developments of 2TRAIN, a universal simulator for all

European countries is not realistic due to the current individual company standards in training technology and the investments made in the past on simulation technology. Instead, a common data simulation interface will be developed within 2TRAIN to allow a standardised data recording and to provide the opportunity to implement simulator add-on systems. These add-ons will be a rule-based expert system, a virtual instructor, and an assessment database. The common data simulation interface will also ensure that the system can be expanded to new technological developments. To spread the results of 2TRAIN to as many interested stakeholders as possible a user group was established. The user group consists of further train operating and railway related companies of different countries that are interested in participating in the project. Bringing in expertise in the benchmarking process about existing procedures and research the user group helps to include the users' needs in the process and to reach a wide dissemination of the results.

1.2 Objectives of the benchmarking report

This benchmarking report summarises training concepts, i.e. training methods, contents and training models, used in 18 European train operating companies. Not only national railway companies were included in the benchmarking process but also companies operating within the area of urban and suburban traffic. The benchmarking process mainly focuses on the usage of computer-based training methods, especially training simulation. In the following chapters the characteristics of training systems and concepts of these 18 companies will be analysed and compared.

A major strategic objective of 2TRAIN is to increase safety and efficiency within the European railway sector. But in what other way should safety and quality of provided services be increased than by improving the actual

training of the personnel involved in railway operation?

A significant number of railway companies were addressed and agreed to provide information about their training tools and its usage. This benchmarking approach is absolutely necessary in the context of European research as the differences among individual companies are outstanding. The benchmarking process guarantees an exchange of experiences from companies operating in different geographical areas of Europe with different training concepts due to different traditions, national laws, or internal rules. During the benchmarking two different methods of data collection were used:

(1) a screening questionnaire and (2) face-to-face interviews on the basis of a key question form. The structure of the questionnaires and interviews was focused on training schedules, topics, methods, and organisational issues. Additionally, the companies were asked for shortcomings and drawbacks of their training tools as well as for future improvements planned.

The aim of the benchmarking report is to describe the current situation concerning computer-based training in different European companies and the settings under which computer-based training is applied. It is illustrated, how different types of companies (e.g. metro vs. railway) conduct the individual training and education by means of driving simulators or CBT/WBT modules.

The results of the benchmarking also give evidence for the distribution of simulator training in different stages of training (initial, advanced and competence check) and for different training topics.

2. Benchmarking process



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2.1 Introduction

In the context of 2TRAIN, the term benchmarking means the comparison of current practices of training in the railway sector with best-practices and accepted standards. This includes an evaluation of the current status applied in the education and training of train drivers. The method of benchmarking has been chosen for 2TRAIN, because it is necessary to be aware of the current situation in the area of railway training and subsequently to compare this situation with the needs of the European stakeholders in this area. Furthermore, a comparison of existing standards and the current situation highlights the gaps that should be improved by the next steps in the course of 2TRAIN, i.e. the research activities and the technical development of simulator add-on tools. The benchmarking process consists of several phases of research: From obtaining information connected with

technical and content-related standards of train driver training through sending a number of different questionnaires and carrying out face-to-face interviews focused on information about the training concepts of different European railway companies, to the analysis of the gathered data.

2.2 Description of benchmarking methods

The data for the comparison of the individual railway companies has been gathered by members of the project team using two subsequent steps: As a first step, a short questionnaire was developed and sent to railway undertakings in Europe. After the analysis of the results of this screening questionnaire, a sample of 18 railway companies was selected for detailed face-to-face interviews and the accordant key question forms were developed. The next step was to hold the interviews with representatives of the selected companies. In particular, the results of these face-to-face interviews are outlined in this report.

Screening questionnaire

The screening questionnaire was mainly prepared with the idea of obtaining a basic overview of simulator types and CBT/WBT modules that are used in European railway companies and how these tools are implemented in the overall training concept. The questionnaire was divided into two sections: The first part asked for information about technological aspects of the simulation systems. The second was related to training contents realised in simulator and/or CBT/WBT modules. At this stage the effort was focused on obtaining information from as many train operating companies as possible. The screening questionnaire was sent to more than 75 companies (railway, metro and light rail operators) from more than 20 European countries. 41 completed questionnaires were sent back. In the following, a summary of the main findings of the screening is given: 23 of the 41 companies are already using simulators for the training of train

drivers. Another three were in the process of purchasing simulator(s). The main topics for using a simulator were: (1) handling of irregularities in railway operation (e.g. malfunctions of technical equipment), (2) operation of train control systems (e.g. automatic train protection), and (3) driving under normal conditions (e.g. driving, braking and operational rules). CBT/WBT modules are mainly used for the acquisition of basic technical knowledge and for rolling stock training. Nearly all of the responding operators report that the training session at the simulator is supervised by an instructor (in contrast to an autonomous learning trainee).

A full replica cab without motion system, small driver desks without a cab, and software interfaces of the cab equipment are most widespread (each approx. 25%). The type of the trainee's desk has consequences for the architecture of the simulator system. Stand-alone application (one or more single simulators, not connected to each other by a network), local network, and distant network (several

training centres interconnected by means of internet or intranet, e.g. for software update) are used by a third of the railway companies each. The most frequently used operating system is Windows, followed by Linux and SGI. Real tracks with real surroundings are used by 18 companies, generic tracks with generic surroundings by 13 companies, and real tracks with generic surroundings by another ten companies. The total length of tracks per system varies enormously with a minimum length of 35 km up to a maximum length of 1400 km.

Face-to-face interviews

A more detailed key question form (KQF) was prepared mainly with the objective of obtaining the most comprehensive overview of (1) computer-based training technology including the users' view and experiences, (2) the usage of these tools for the training of different training contents and a comparison with other (conven-

tional) training methods, (3) specific training modules dealing with abnormal operational situations and human factor contents, and (4) the concept and organisation of training with a special focus on the competence assessment:

Description of training technology

This section of the KQF deals with technical specifications and standards of e-learning tools and simulation technology. Additionally, the users' view regarding the importance of different technical features, the level of fidelity reached by the existing systems and an overall evaluation regarding the day-to-day application is covered.

Usage of simulators and CBT/WBT modules

This section of the KQF asks for the reasons for purchasing simulators and whether over the course of recent years there has been a change of attitude towards the usage of simulators in the area of training of train drivers. Another important question is the extent of the usage

of simulators during initial training, advanced training, and competence checks. The respondents report which topics are trained by using simulator exercises or CBT/WBT modules. These topics have been divided into two groups:

a) Basic topics

- Driving under normal conditions (train preparation, driving, braking, signal system, operational rules, etc.)
- Basic technical knowledge (knowledge about technical systems and procedures: maintenance of engine, construction, technique of brakes, etc.)
- Irregularities during train operation (handling of irregularities in railway operations and in technical installations: driving backwards, running on sight, malfunctions on the locomotive/train, etc.)
- Shunting
- Operation of train control systems (e.g. automatic train protection, automatic train control)
- Route knowledge
- Rolling stock

b) Specific topics

- Decreased adhesive circumstances (slippery rails)
- Emergency situations (handling of incidents/accidents: e.g. fire in train, derailment, collision)
- Energy-saving driving (green driving)
- Customer-oriented behaviour (e.g. announcements for customers)
- Human factors training (human behaviour topics: e.g. handling of multiple tasks, communication skills, decision making)
- Occupational safety (safety precautions)
- Cross-border operations
- Coupling/Uncoupling
- Cooperative training (signaller and train driver are trained together)

In the summary part of this KQF section, tables have to be filled with a percentage estimation reflecting the amount of current training in one topic that is done

with different training methods. For the six topics (initial training, advanced training, competence check, rolling stock, route knowledge, ATC/ATP) the respondent has to estimate the used training method (classroom, CBT/WBT, simulation, real cab, other). Furthermore, the expert from the company's training department should estimate (again as a percentage value) to what extent different types of simulators (software interface of cab equipment, small driver desk without cab, partial cab, full replica cab without motion system, full replica cab with motion system) are used for the training of these topics.

Training modules

The objective of this part was to collect detailed data about specific training modules whose contents are of central interest to the 2TRAIN project (abnormal/irregular conditions, emergency situations, human factor). Furthermore, the respondent should add information

concerning unique or forward looking modules of interest. For every described training module a separate template should be filled in.

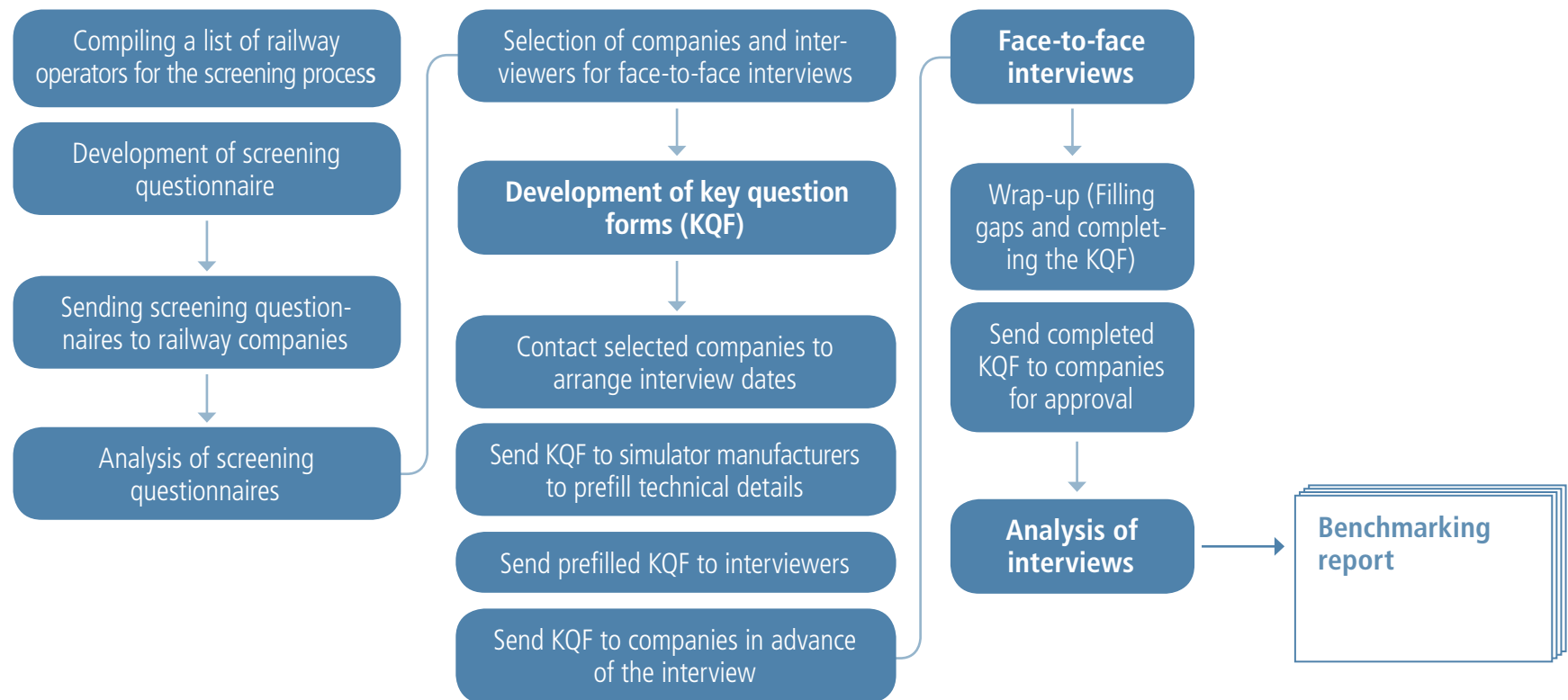
Organisation of training

This section is focused on general and organisational aspects of the training system for train drivers. This concerns mainly information related to training on simulators.

The questions focus on:

- How is the actual training conducted? (centrally or locally)
 - Who is responsible for the actual training? (internal instructors, instructors from the training department of the company, external company)
 - Who is responsible for the development of training modules? (internal instructors, instructors from the training department of the company, external company)
 - Which regulations are important for the training concept? (national legislation, company regulation)
 - Is there any assessment to assess trainees' competence? (CBT knowledge test, assessment drive on simulator)
 - Is there an assessment scheme for simulation trainings? (after initial training, after a dangerous incident/ accident, regular competence check)
 - Which information sources are used for performance assessment at the simulator? (unstructured observation, structured observation using an assessment sheet, objective simulator data)
 - Are the results of training stored?
 - Are there any external clients using free training capacity at the training department?
 - Was the procedure of simulator or CBT/WBT training evaluated?
 - Are there any shortcomings and drawbacks concerning technical aspects, learning contents, training organisation, or acceptance linked with the usage of simulators?
-

The face-to-face interviews were carried out by members of the 2TRAIN project team. The interviews were held with the companies' representatives responsible for the training of train drivers, i.e. the training manager, the trainers and the training developers. For preparation and in order to support the successful completion during the face-to-face interviews, the KQF was sent to the companies beforehand with the objective to prepare the interviews by gathering the necessary data. The technical part of the KQF was additionally sent to the simulator manufacturers for the provision of the technical details. The overall concept of the interview method was based on the flowchart shown in Figure 1.

Figure 1: Flowchart of the Benchmarking Process

2.3

Interviewed railway companies

The idea and concept of the whole benchmarking process was to select companies with different main subjects of activity (railway companies, companies operating in urban transport or light rail). The list of the interviewed companies is given below:

Table 1: List of interviewed light rail and metro companies



















Company logo	Name	Metro	Tram	Rail
	MdM	×	×	
	SSB		×	
	TMB	×		
	VAG	×	×	

Table 2: List of interviewed railway companies











Company logo	Name	Metro	Tram	Rail
	CFL			×
	S-Bahn Berlin			×
	SWT			×
	MAV			×
	CD			×
	FSR			×
	NSB			×
	Southern Railways			×
	IE			×
	RENFE			×
	SNCB			×
	DB			×
	Trenitalia			×
	SNCF			×









As countries from western, northern, southern, and eastern parts of Europe are involved in the benchmarking process, the research sample represents the whole spectrum of railway operators in today's Europe. The 18 railway companies (14 railway operators and four metro and light rail operators) involved in the face-to-face interviews represent more than 600 000 employees, of which are approximately 78 000 train drivers (Table 3).

Figure 2: Representation of companies according to individual EU countries



Table 3: Information concerning the representativity of the interviewed companies

Company logo	Name	State	Employees	Train drivers	Train drivers in training	Kilometres operated
	CFL	Luxemburg	3 100	320	0	275
	CD	Czech Republic	57 246	6 610	25	9 000
	DB	Germany	225 000	20 500	500	34 000
	FSR	United Kingdom	7 500	850	30	n/a
	IE	Ireland	4 800	500	61	1 700
	MAV	Hungary	40 000	3 500	0	7 000
	MdM	Spain	6 000	1 600	15	233
	NSB	Norway	2 800	684	60	4 000
	RENFE	Spain	15 000	5 000	92	n/a
	S-Bahn Berlin	Germany	n/a	960	0	331

Company logo	Name	State	Employees	Train drivers	Train drivers in training	Kilometres operated
	SNCB	Belgium	15 000	3 891	290	3 544
	SNCF	France	170 000	15 000	900	30 000
	Southern Railways	United Kingdom	n/a	850	60	650
	SSB	Germany	n/a	900	43	130
	SWT	United Kingdom	n/a	1 200	0	n/a
	TMB	Spain	n/a	1 200	300	120
	Trenitalia	Italy	55 000	13 929	831	15 500
	VAG	Germany	1 800	310	40	40
Total			603 246	77 804	3 247	106 523

3. Description of CBT/WBT systems



Chapter 3

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3.1 General information

This section starts with general information about the training modules, continues with more technical details and ends with subjective questions displaying the users' view. The usage of CBT/WBT modules is quite different from company to company and only ten out of 18 interviewed operators actually provide some kind of CBT/WBT application at all. Some undertakings use this method as a teaching reinforcement to support the instructor, others mainly utilise the e-learning tools as a self study method and others make use of the assessment capabilities. Most CBT/WBT tools are developed by external companies and only a few within the training department of the railway undertaking.

The analysed CBT/WBT systems were delivered from 1996 to 2007, 30% of them have been upgraded since the date of delivery. Improvements implemented in these upgrades are mainly related to network connections

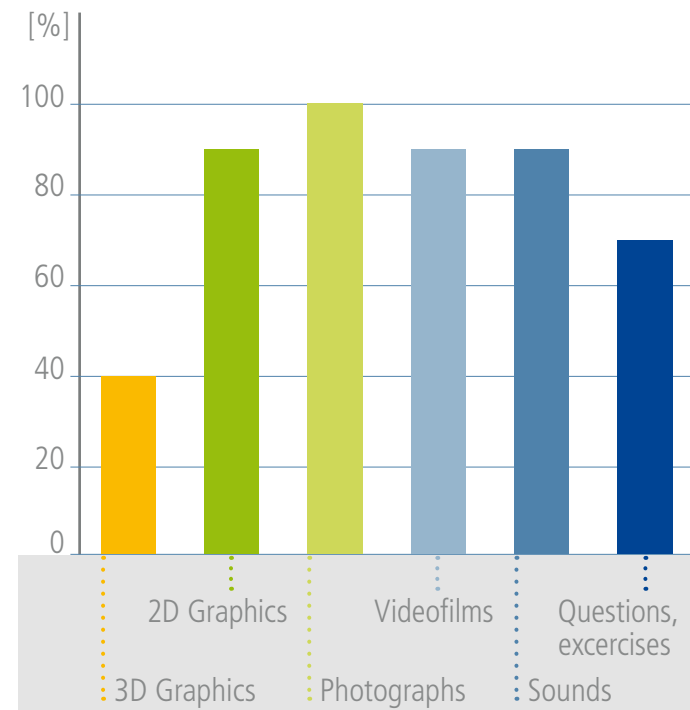
and the addition of new content. The development phase of a CBT/WBT application lasts from a month up to two years, resulting in an average development time of approx. nine months. General characteristics of the analysed CBT/WBT are illustrated in the following graphs.

3.2 Technical specification

As is reflected in Figure 3, 3D graphics are only implemented in 40% of all CBT/WBT modules.

Figure 3: Different media types

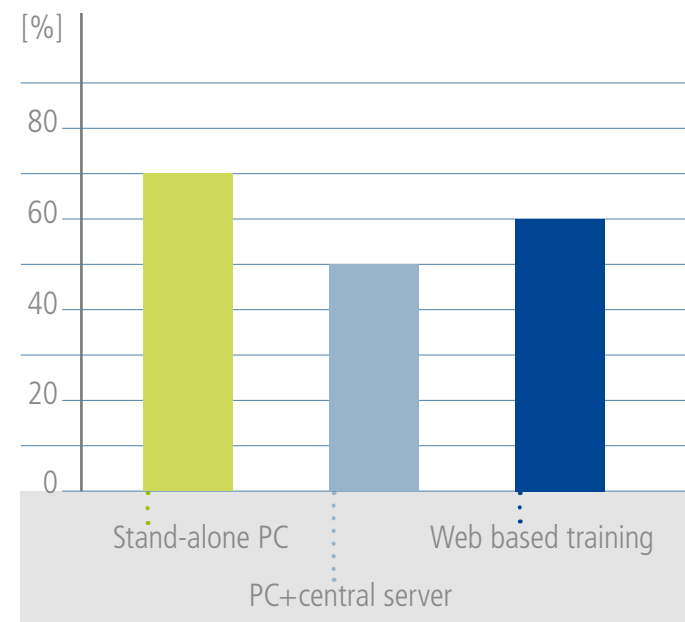
Sample: 10 companies



All CBT/WBT systems run under MS Windows. Only one CBT was found that is able to run also under Linux. The next graph shows that seven companies run modules on a stand-alone PC, five companies run CBT/WBT modules on a PC that needs the connection to a central server and six of the analysed companies use computer-based training that is accessible through a web browser, i.e. web-based training. Note that several modules can run in more than one environment. The connection to the central server is mainly used for the storage of results in a central database.

Figure 4: Running environment of CBT/WBT systems

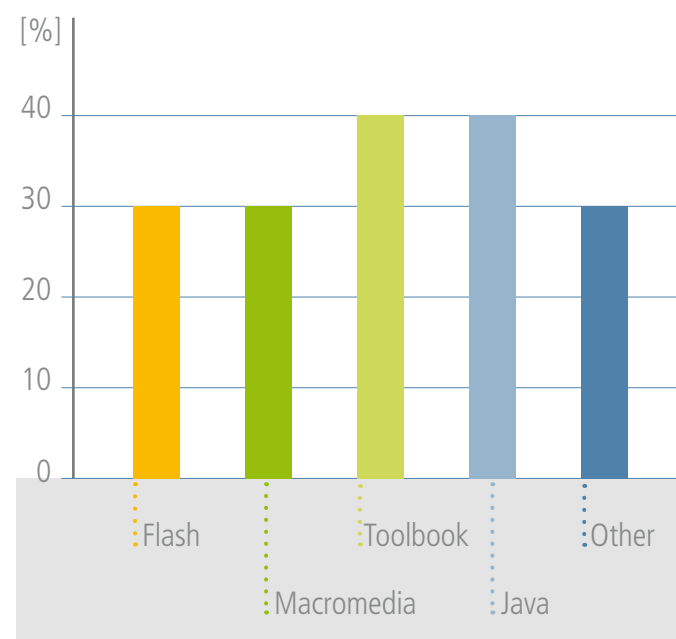
(Sample: 10 companies)



Concerning the structure of the network eight out of ten railway undertakings use a local network, six companies use the infrastructure of the intranet and only two companies allow a remote access. CBT/WBT applications are programmed in a great variety and by means of a combination of different software tools. Java and ToolBook are the most prominent ones in the benchmarking sample.

Figure 5: Programming language and authoring tools of CBT/WBT applications

(Sample: 10 companies)



Four companies use CBT/WBT modules without any capability of storing assessment data. The databases in usage are based on different database formats, e.g. Oracle, Access, MySQL, and BorlandInterbase. Often, the CBT/WBT systems follow no standard at all. Nevertheless, in some cases SCORM¹ (Sharable Content Object Reference Model) and AICC² (Aviation Industry Computer-Based Training Committee) are used.

¹ SCORM is a collection of standards and specifications for web-based e-learning. Its development started in the Department of Defence of the USA Government, but nowadays some of its regulations are part of the IEEE standards.

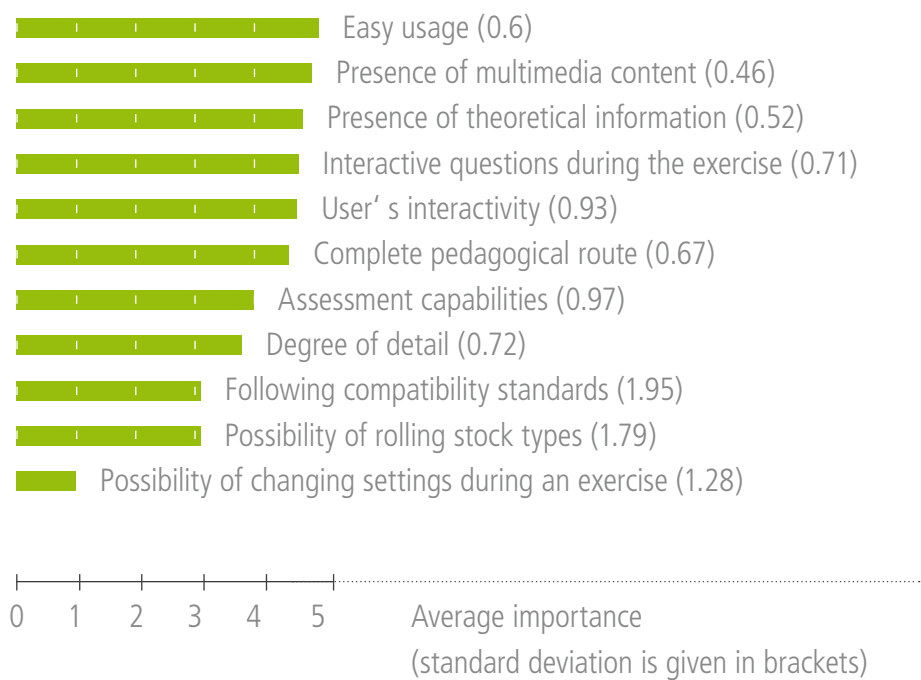
² This committee was developing guidelines for CBT mainly for the aviation industry, but later they evolved to other fields. Currently AICC still publishes these guides but has lost strength with the creation of SCORM.

3.3 Expectations and evaluation

Operators were asked about the importance of several aspects and features of the CBT/WBT modules. The instruction was: "Please indicate the importance (or necessity) of a variety of features expected in a CBT/WBT module. Please note that it is not necessary for these characteristics to be present in the analysed CBT/WBT." The next table shows the average results.

Figure 6: Importance of several features of CBT/WBT systems

(Sample: 10 companies)



Three items that might be difficult to understand were explained as follows:

- Complete pedagogical route: The content of a course should be general and therefore will teach about all train or line systems (5) or should focus only on some specific systems (1).
- Degree of detail: The CBT/WBT learning content about specific systems of the trains should be light (1) or in depth (5).
- Following compatibility standards:
The importance given to the following e-learning standards like SCORM.
- Possibility of different rolling stock types:
The advantage of using a CBT/WBT for training in connection with several specific trains instead of having several CBT/WBT.

The figure reveals that for operators, the ease of usage of the CBT/WBT system is the most important topic. This

fact has an easy explanation; if a CBT/WBT is difficult to use it will not be used at all. Other highly rated topics are the presence of multimedia content and the presence of theoretical information. These two topics have such a high importance, because they are related to the main CBT/WBT objective: teaching. All companies believe that CBT/WBT must have theoretical information and this information should be as illustrative and comprehensible as possible.

4. Description of simulation systems



Chapter 4

4.1	General information	35	4.3	Simulation capabilities	48
4.2	Technical specification	37		Subsystems	48
	Computer and communication system	37		Rail traffic and signalling	50
	Programming language	40		Road traffic and pedestrians	51
	Trainee desk	41		Lines	53
	Visual system	43		Settings	54
	Sound system	45		Modelled elements	55
	Motion system	47	4.4	Expectations and evaluation	57

4.1 General information

The benchmarking results are based on the analysis of 138 simulator systems operated by 17 different railway companies and developed by eight different manufacturers: Citef, Corys T.E.S.S., EADS, Indra, Krauss-Maffei Wegmann, Lander, OKTAL, and Sydac. A description of different types of simulators is given in Chapter 5.2. The benchmarking process comprised 138 simulator systems in total. Figure 7 and table 4 shows how these systems are divided into the five different types of simulators. The train operating companies may have further simulators in use than presented in this report. It was the choice of every company which system should be part of the enquiry. For example, SNCF laid the focus on its TGV high speed simulators. Therefore, only these systems have been included in the benchmarking besides the fact that SNCF also runs other systems.

Figure 7: Simulator types

(Sample: 138 systems)

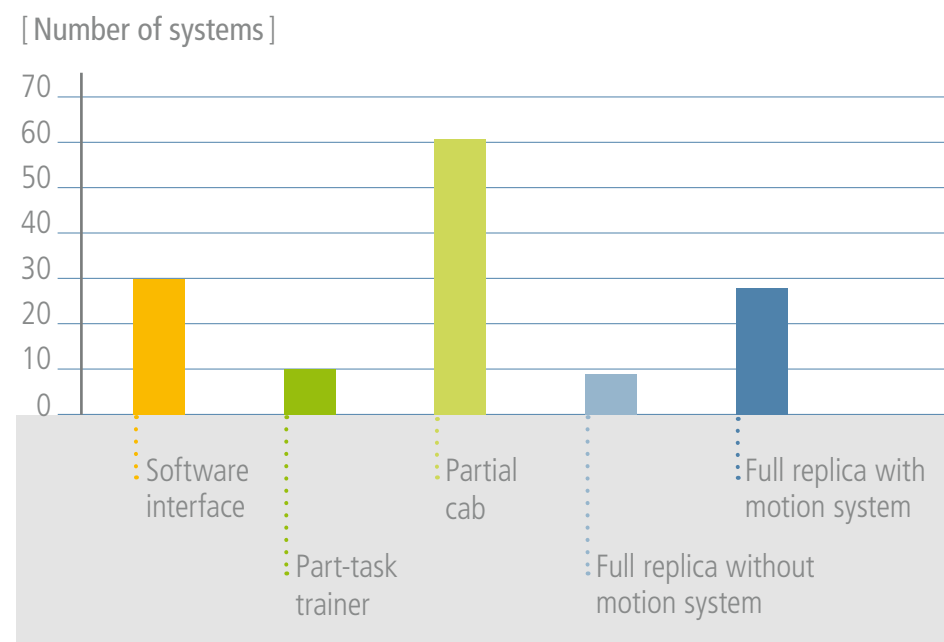


Table 4: Number of analysed systems per simulator type and company

	Type A	Type B	Type C	Type D	Type E
CFL	-	10	-	-	1
DB	-	-	-	-	16
FSR	-	-	-	2	-
IE	-	-	1	-	-
MAV	-	-	2	1	-
MdM	10	-	-	2	-
NSB	-	-	5	-	1
Renfe	-	-	3	-	-
S-Bahn	-	-	-	-	1
SNCB	-	-	31	-	2
SNCF	-	-	12	-	2
Southern	-	-	5	-	-
SSB	-	-	-	-	1
SWT	-	-	-	4	-
TMB	20	-	-	-	-
Trenitalia	-	-	-	-	4
VAG	-	-	2	-	-
Total	30	10	61	9	28

The first simulator systems were delivered in 1995, the most recent ones in 2007. Nearly 50% of the analysed simulators have already been updated. The improvements were very diverse, from setting up new projection systems to changing the whole train model. The time for developing a simulator (from specification to delivery) varies between six and 36 months with a peak at 24 months. Actually, only one type of the analysed simulators has the capability for real simultaneous training, i.e. two or more trainees driving simultaneously in the same scenario on different simulation systems, meanwhile a traffic manager controls the traffic and the signalling of the line. In addition, an instructor is supervising the whole exercise. This simulation system is installed at Metro de Madrid.

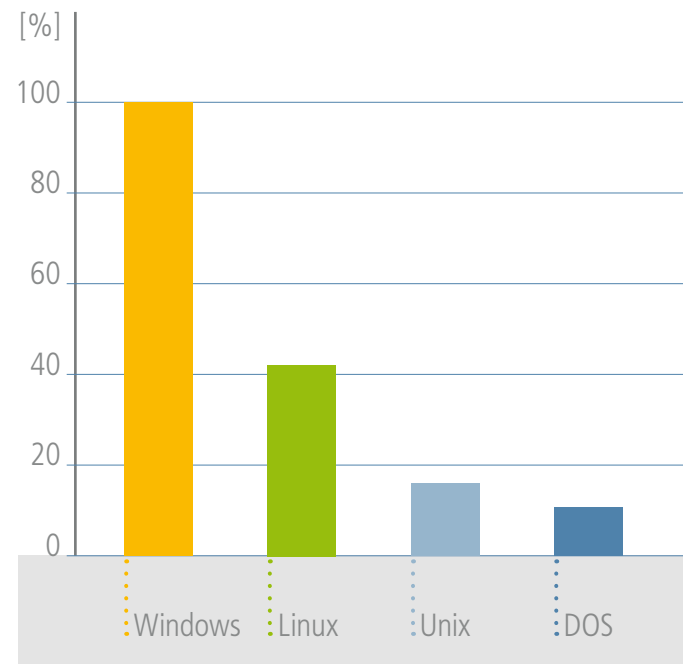
4.2 Technical specification

Computer and communication system

All simulators run under different versions of MS Windows. In addition to MS Windows, some simulators use other operative systems for specific tasks (e.g. to generate the infrastructure). The usage of Linux is increasing year by year, maybe due to its open source and multitask possibilities. MS DOS simulators were only developed in the past. Furthermore, UNIX simulators were developed for running in expensive workstations, nowadays some of them are ported to Linux.

Figure 8: Simulators' operative systems

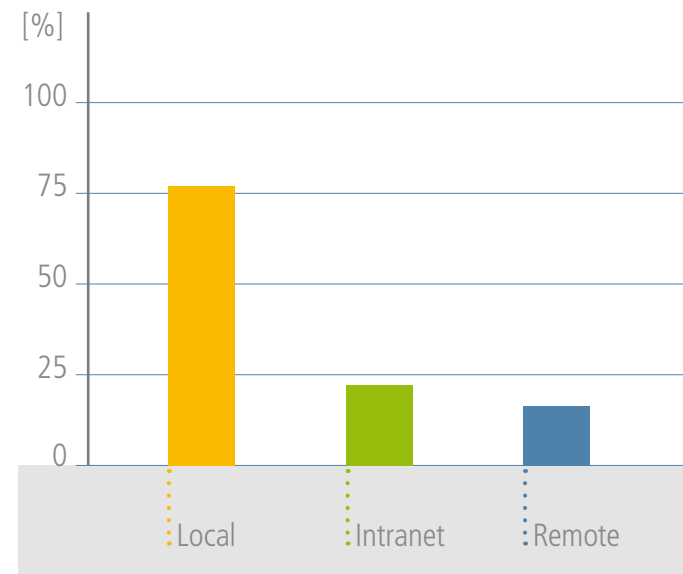
(Sample: 17 companies)



Approximately 90% of simulators are distributed applications, i.e. running on more than one computer. 75% of simulators are implemented in a local network, nearly 25% run via intranet. Another 20% of the systems can be accessed through remote connections, but usually for administration, not for training purposes.

Figure 9: Simulators' networks

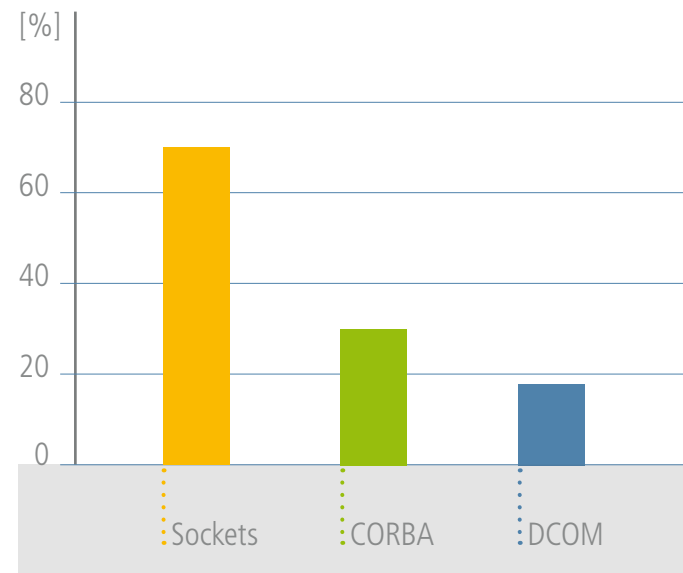
(Sample: 17 companies)



About 70% of all simulators use sockets directly and approx. 50% use high level object-oriented protocols, like CORBA or DCOM. Note that several simulators use more than one technology. Despite the fact that MS Windows is used in all simulators, only 20% use DCOM as communication protocol. Maybe due to established habits, the combination of object-oriented communication systems (CORBA and DCOM) has not yet taken a lead over sockets. Nearly all simulators are based on TCP/IP as communication protocol, only one uses UDP.

Figure 10: Simulators' communication protocols

(Sample: 17 companies)



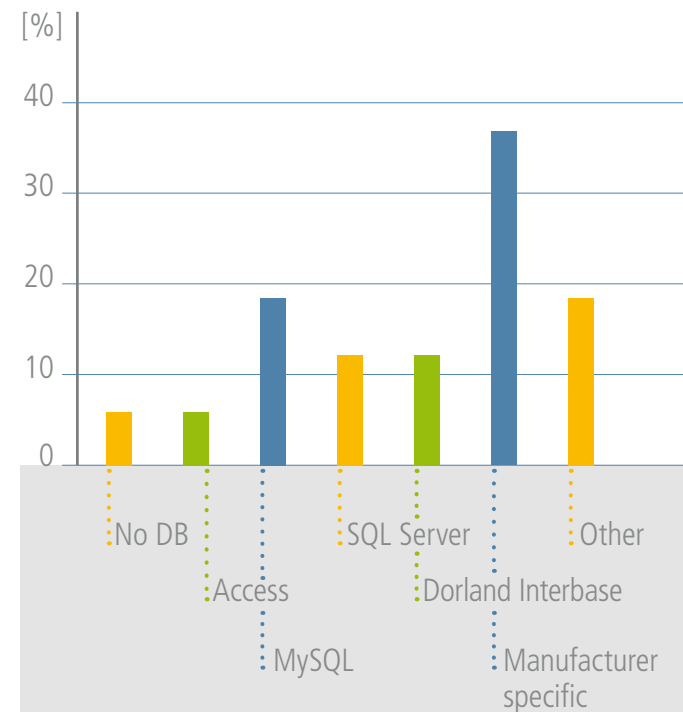
Programming language

All simulators are programmed in C/C++ whereas a small percentage of them use other languages like inventor or php for specific purposes. Figure 11 shows the assessment database format. There is not a unique standardised format: About 35% of simulators use a manufacturer specific format. Other formats are MySQL, SQL Server and Borland Interbase.

With regard to standards, none of the studied simulators follows any simulation standard (like DIS or HLA).

Figure 11: Simulator database format

(Sample: 17 companies)

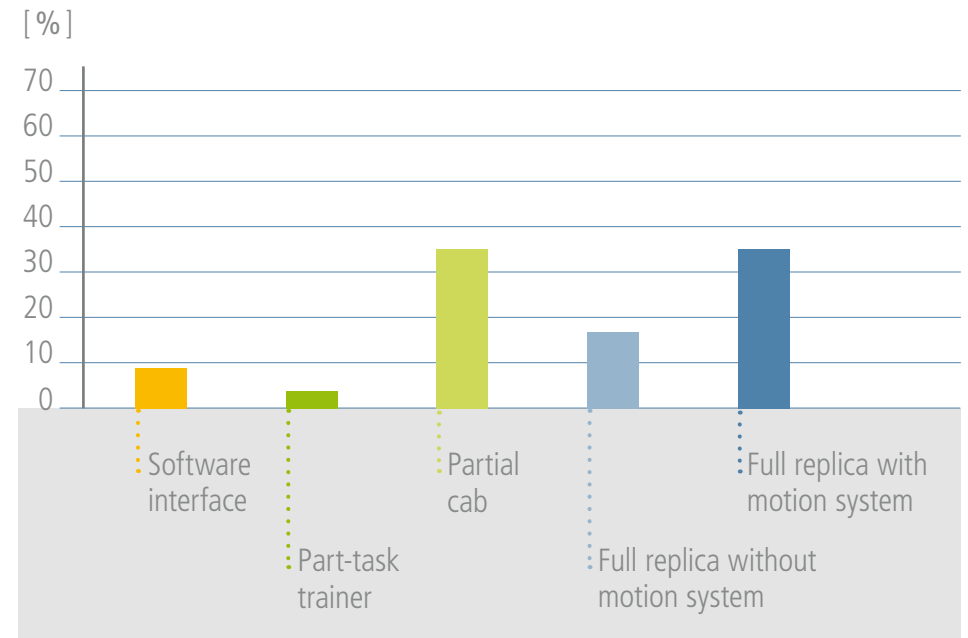


Trainee desk

As reflected in Figure 12, five different types of simulators are differentiated in the frame of the study: (A) software interface of cab equipment, (B) part-task trainer, (C) partial cab, (D) full replica cab without motion system, and (E) full replica cab with motion system. About 35% of the analysed systems are partial cab simulators, another 35% simulators are equipped with a full replica cab and motion system, and 17% are equipped with a full replica cab but without a motion system. Software interfaces are used in 9% and part-task trainers due to the limited field of application in only 4% of the sample. Several companies have decided for a combination of simulators in terms of scalability as to cover the wide range of applications up to a full-mission simulator on the one hand, and to guarantee a high amount of simulator training by cost-effective partial-cab solutions.

Figure 12: Trainee desk configuration

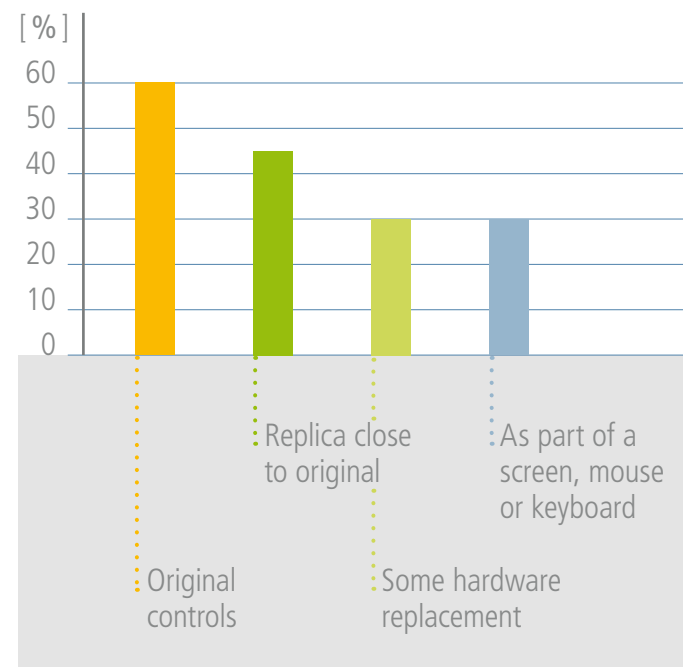
(Sample: 17 companies)



About 60% of the simulators have original controls; 45% of simulators have them as a replica close to the original. In addition to physical controls, some simulators have other systems to show and manipulate secondary controls or actuators (e.g. for circuit breakers).

Figure 13: Simulator controls

(Sample: 17 companies)



Visual system

The visual system characteristics of the analysed simulators are very diverse. In relation to the field of view, the next two graphs show both horizontal and vertical fields of view. In terms of visual resolution, 1280x1024 is present in more than 40% of the analysed simulators. This parameter does not seem to be influenced by the technical advances in the recent years. Each simulator has a different screen size. There are simulators that run with a common 19" screen, while others have a large projection screen (10m x 4m). Presentation systems are also different: In addition to PC screens, there are simulators with projection and retro-projection systems. About 80% of simulators have a 60 fps visualisation frequency; another 20% run with 30/33 fps. Besides the fact that human eyes do not make out more than 24 fps, most manufacturers prefer to have a 60Hz visualisation frequency in order to reduce eye strain. A rear view is present in 42% of the studied simulators.

Figure 14: Horizontal field of view

(Sample: 12 companies)

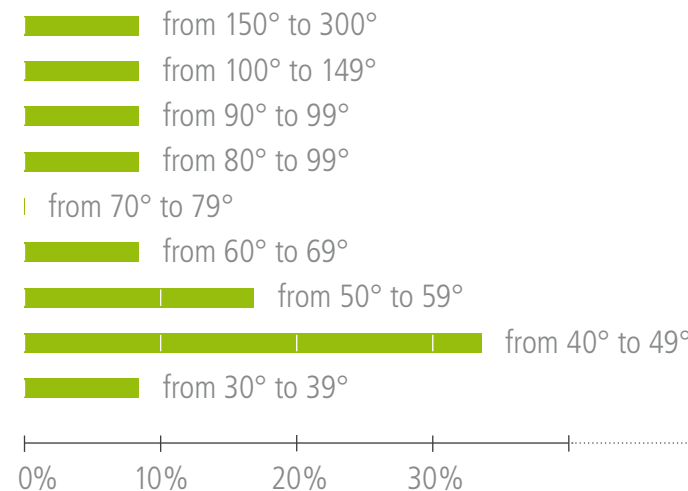
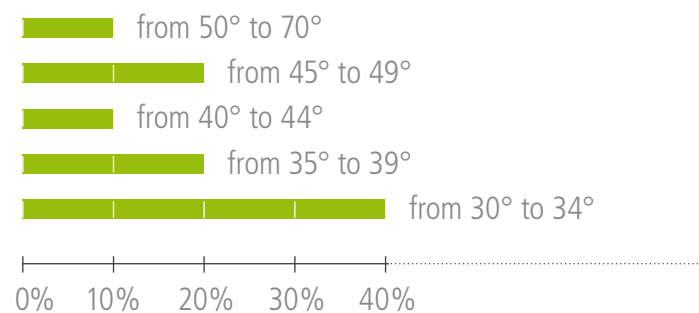
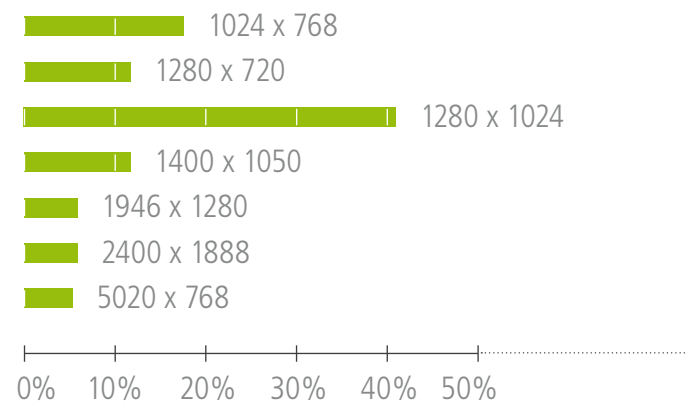


Figure 15: Vertical field of view

(Sample: 10 companies)

**Figure 16: Visual system resolution**

(Sample: 17 companies)

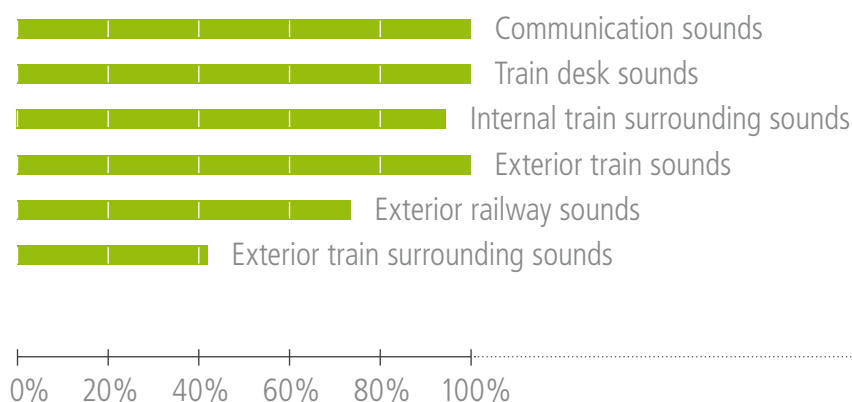


Sound system

As far as sound is present in the simulator, it reproduces communications, sounds of the trainee desk (like buzzers, beeps or sound messages) and exterior train sounds (like rolling on different features or electro-magnetic brakes). Other sounds present on some simulators are internal train surroundings sounds (e.g. doors, communication, pneumatic system or ventilation), exterior railway sounds (e.g. bells or station announcements) or exterior surrounding sounds (e.g. rain, wind).

Figure 17: Variety of modelled sounds

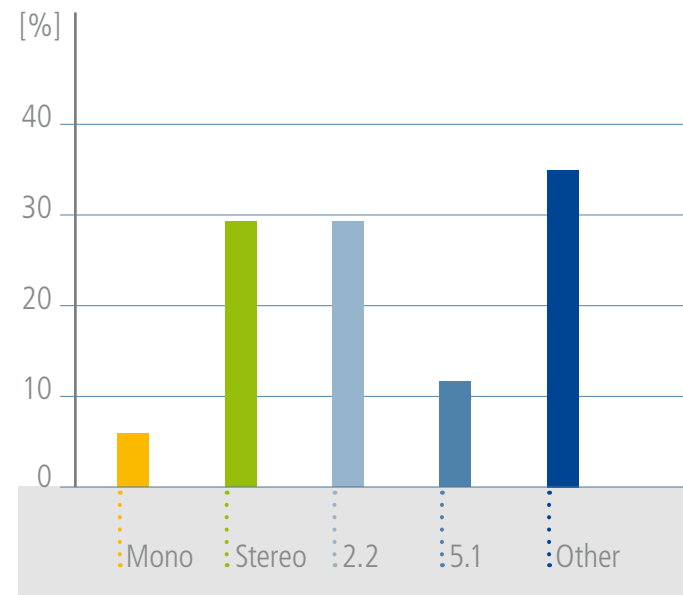
(Sample: 17 companies)



The next graph shows the number of channels of the sound system. Originally, this question asked about cab sounds, but some companies have also included other sounds (for example communications or track sounds). This results in about 35% of the simulators having a specific configuration, for example 6 channels: left channel, right channel, track sounds, message speaker, radio speaker, radio microphone. Furthermore, other present configurations are mono, stereo, 2.2 and 5.1.

Figure 18: Number of sound channels

(Sample: 17 companies)

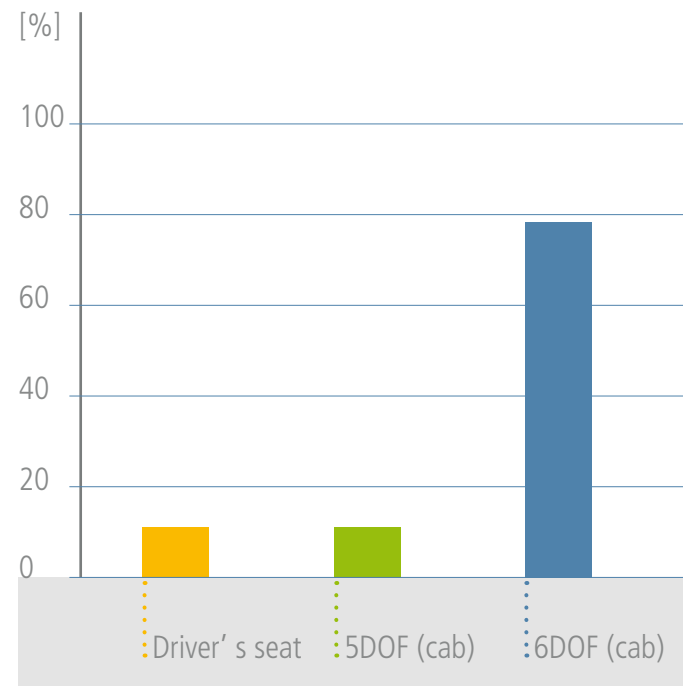


Motion system

50% of the simulator sample has a motion system. Almost all of these systems are full cab motion system with five or six degrees of freedom (DOF). The only exception is a simulator that only has one DOF, i.e. the vertical vibration of the driver seat.

Figure 19: Motion system

(Sample: 9 companies)



4.3 Simulation capabilities

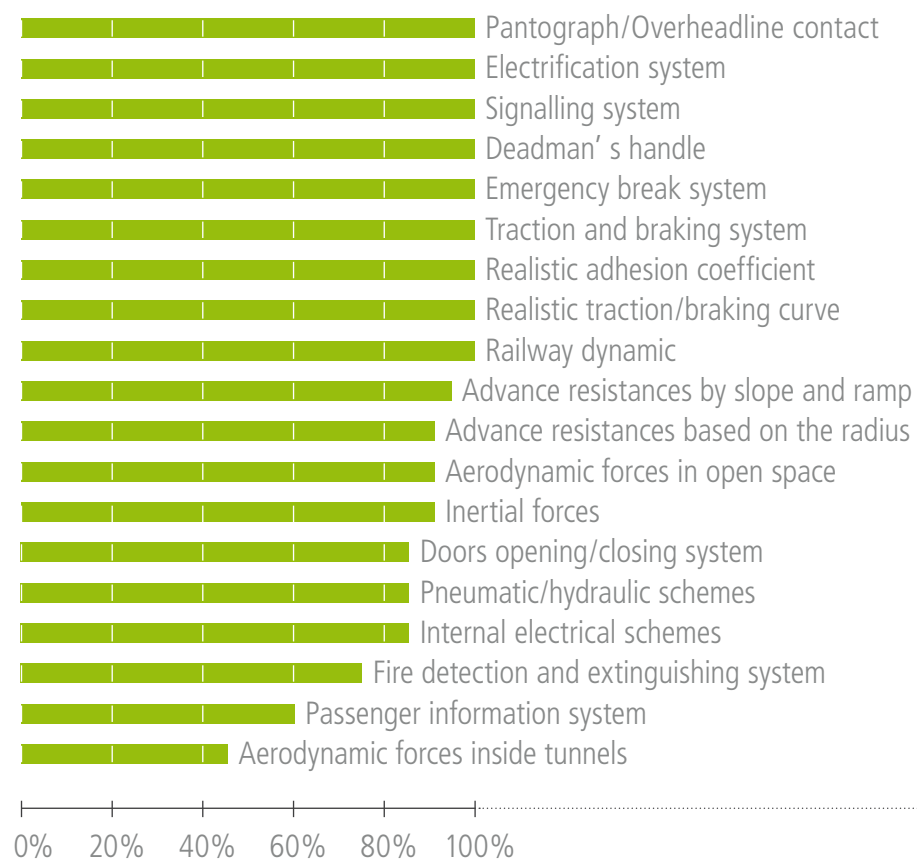
Subsystems

This section informs about the capability of simulators to model different systems or subsystems. Figure 20 shows that all simulators replicate the pantograph/overhead line contact, deadman's handle and the electrification, traction and breaking systems.

Additionally, all of them have a realistic adhesion coefficient and traction/breaking curve. Aerodynamic forces inside tunnels are only modelled in 45% of the systems. Aerodynamic forces are very different among open-sky and tunnels, but are only modelled in underground train simulators, maybe due to the low presence of tunnels in other simulator scenarios. Most of the analysed simulators are focused on driving. Other less related elements, such as the passenger information system is only present in 60% of the simulators.

Figure 20: Modelled subsystems

(Sample: 17 companies)

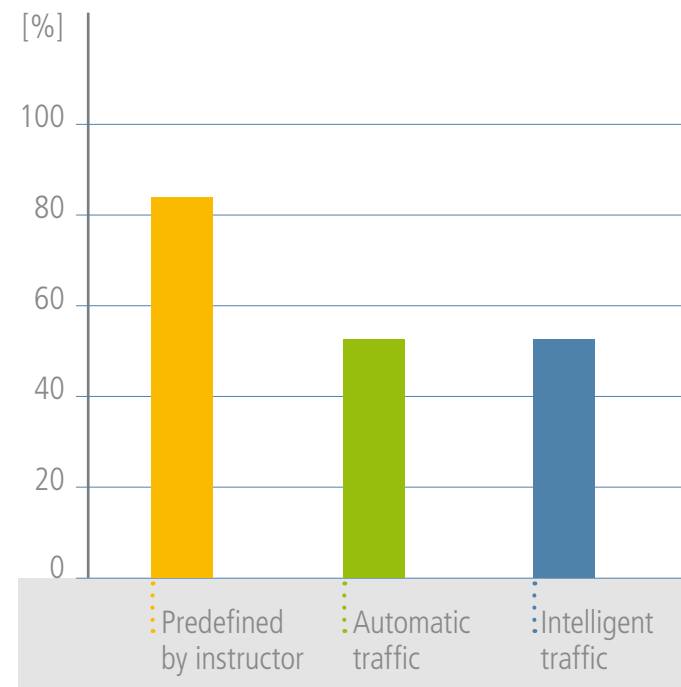


Rail traffic and signalling

In addition to the driven train, 95% of the simulators also represent other railway traffic. Figure 21 reveals how other trains are managed (Note: a simulator can have several modes to manage automatic trains). About 85% of the simulators manage other trains by an event-based system. This means that the instructor is able to determine where and when trainees will encounter another train. With an automatic traffic system trains move without following any regulation, they do not stop at stations nor reduce speed at a level crossing. Finally, intelligent traffic means that the initial positions of these “intelligent” trains are stored in the configuration file such that when the exercise starts, these trains will start driving following all rules and regulations, just like in the “real” world. The sum of the three columns exceeds 100% as some simulators can configure trains in different ways.

Figure 21: Management of other trains

(Sample: 17 companies)

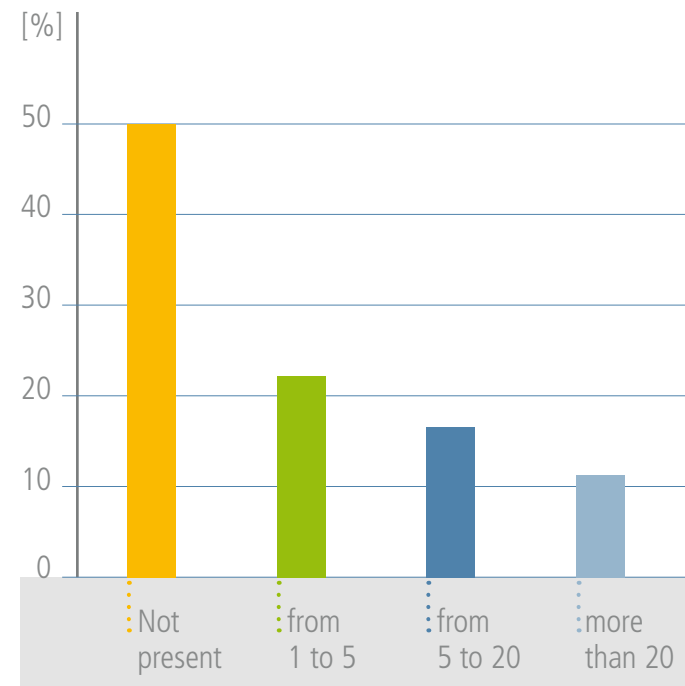


Road traffic and pedestrians

Only 50% of the examined systems simulate road traffic, some simulators reproduce road vehicles only in specific situations, e.g. level crossings. The next graph shows how many different cars can be modelled.

Figure 22: Number of modelled cars

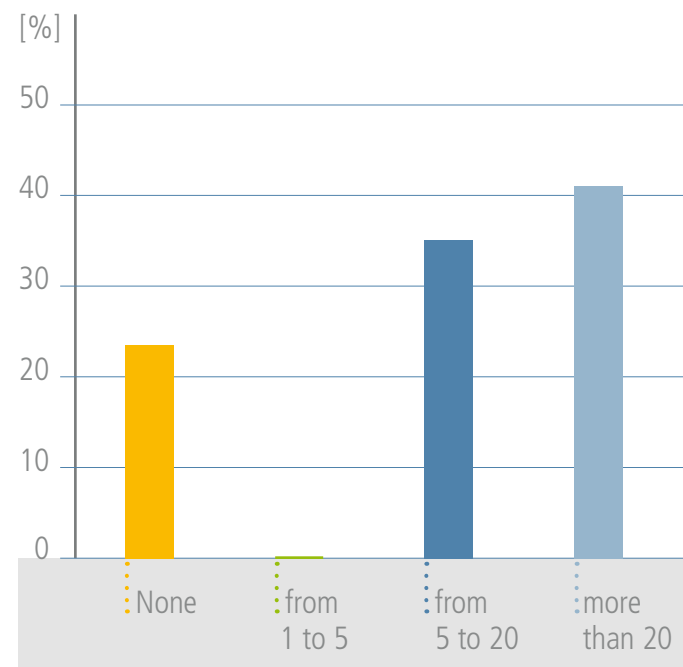
(Sample: 16 companies)



About 75% of the analysed simulators can model pedestrians and/or passengers. Figure 23 examines how many different characters can be simulated. The number of represented pedestrians or passengers is a parameter directly related to technical and process limitations. For that reason, only 40% of the systems simulate more than 20 different pedestrians/passengers. About 70% of all simulators are able to represent boarding.

Figure 23: Number of different pedestrians and passengers

(Sample: 16 companies)



Lines

Most lines of the studied simulator systems are represented as real lines, i.e. real tracks and real surroundings or generic lines (generic tracks and generic surroundings).

Table 5: Simulated lines

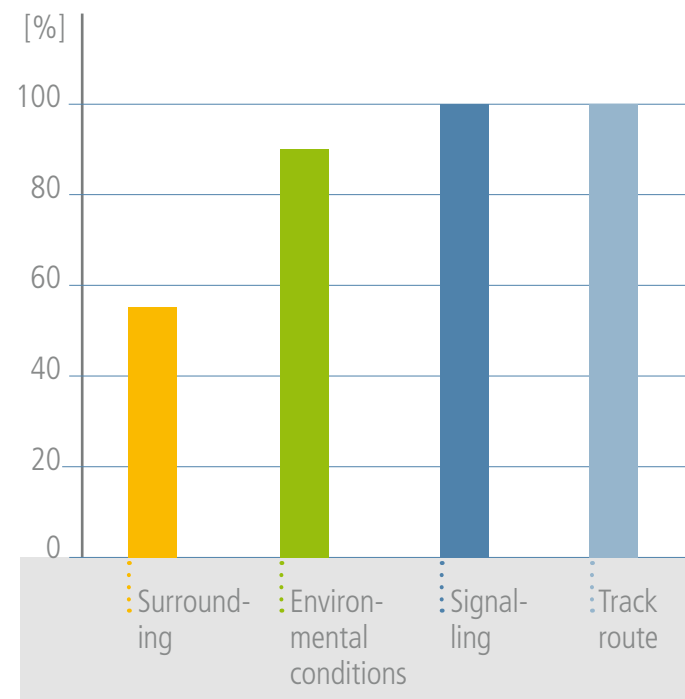
	Number of Lines	Kilometres of track
Realistic lines	27	3 100
Geo-generic lines	10	1 650
Generic lines	24	1 700

Settings

The next graph shows the settings that can be changed during an exercise. All simulators are capable to change signalling (e.g. lights) and the track route, most of them can also change environmental conditions (e.g. weather, daytime).

Figure 24: Settings that can be configured

(Sample: 17 companies)



Modelled elements

Figure 25 shows that all simulators are able to model buffer stops, overhead lines, lights, and signals as line related elements. Beacons and pantograph are present in 80% of them. In addition, Figure 26 displays the surrounding elements that are modelled in simulators. Finally, Figure 27 shows some special effects present in the simulators.

Figure 25: Modelled line-related elements

(Sample: 17 companies)

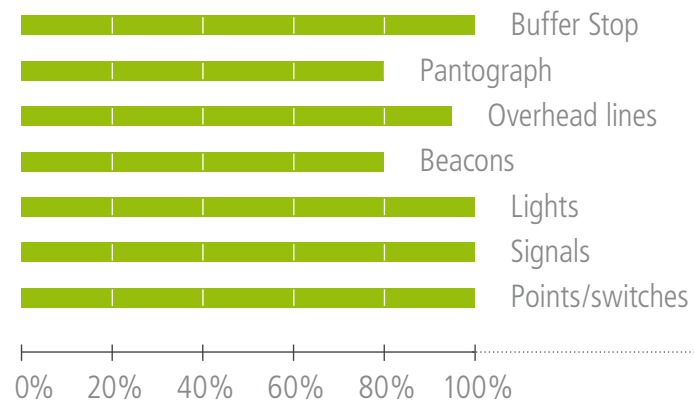
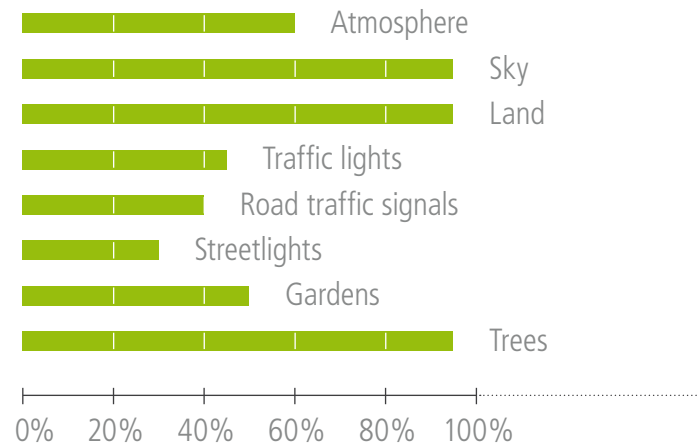
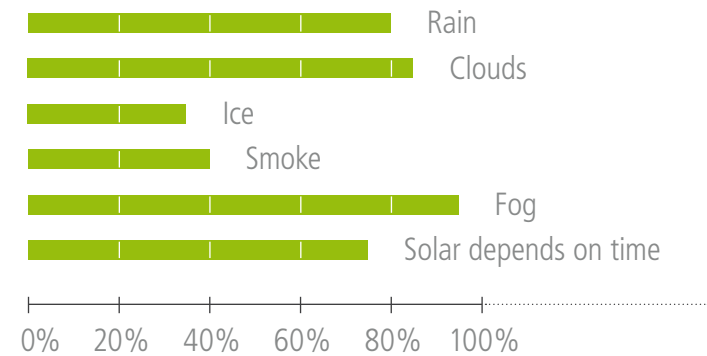


Figure 26: Modelled surrounding elements

(Sample: 17 companies)

**Figure 27: Modelled weather conditions**

(Sample: 17 companies)



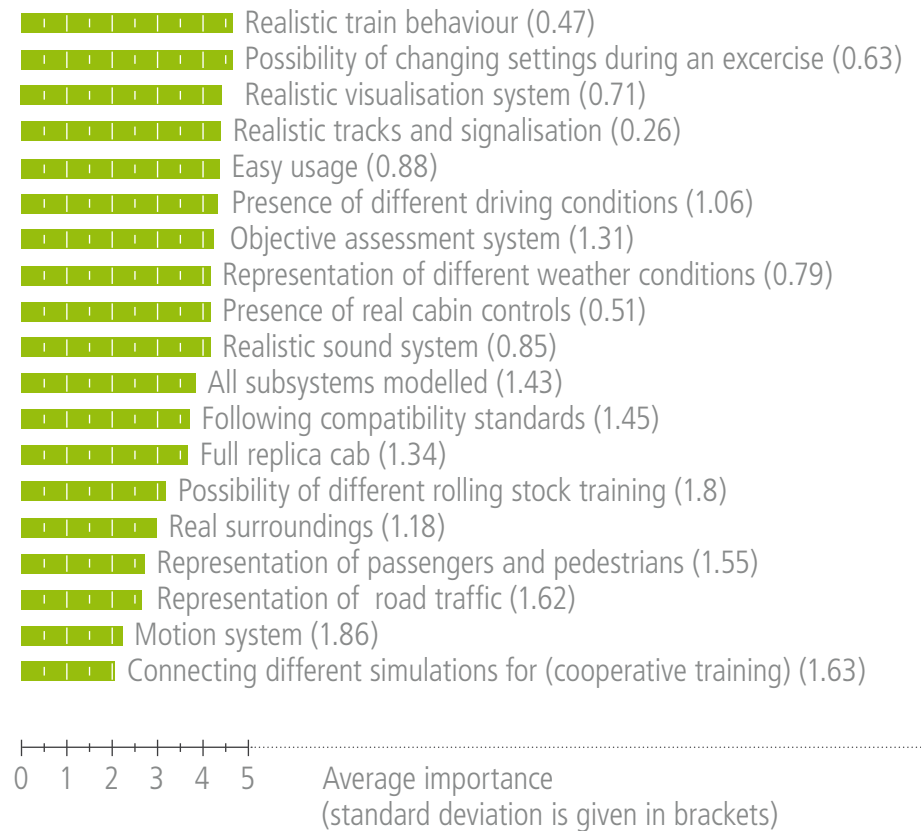
4.4 Expectations and evaluation

The 18 companies were asked to rate the importance of some technical features to be expected from a training simulator on a six point scale (0 = “not important”, 5 = “very important”). The most important features with average ratings above 4.5 are the realistic train behaviour and the possibility of changing settings during an exercise. Average ratings above 4.0 are given for an objective assessment system, real cabin controls, realistic tracks and signalisation, realistic visualisation and sound, different driving and weather conditions. Average ratings above 3.0 are stated for the existence of a full replica cab, for the modelling of all subsystems (e.g. electrical, pneumatic), for the possibility of simulating different rolling stock, and for compliance with compatibility standards. Average ratings below 3.0 are given for the existence of a motion system, the ability to connect different simulators

for combined exercises, the existence of real surroundings as well as the representation of road traffic, passengers and pedestrians. It has to be considered that the scoring on some of these items is greatly dispersed. For example, the motion system is of high importance for those operators running a simulator with motion system but seems nearly unnecessary to other companies.

Figure 28: Importance of several features of simulator systems

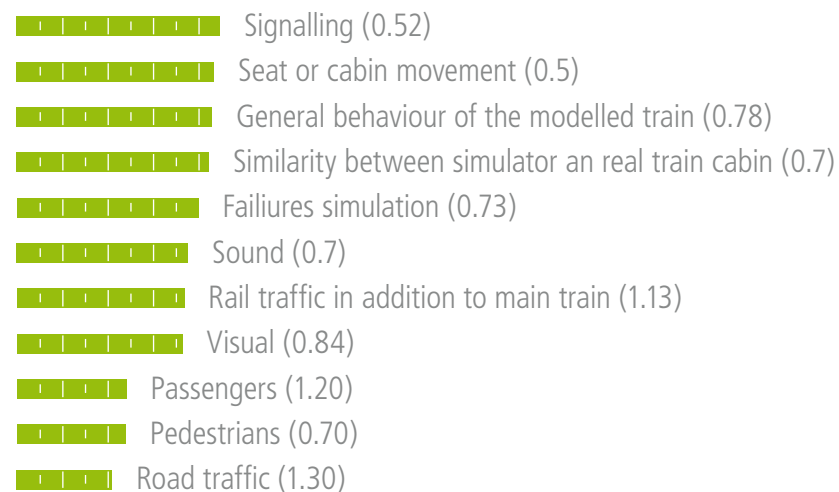
(Sample: 18 companies)



During the interviews, the operators were also asked to evaluate the existing training technology on a six point scale (0 = “simulator does not have the characteristic”, 1 = “Not realistic”, 5 = “very close to reality”) with regard to how close the existing simulators are to reality. The representation of road traffic, pedestrians and passengers are the lower valued items due to the difficulty of emulating human behaviour on the one hand, and the low importance that most operators place on these topics on the other. The mathematical train model, the signalisation system and the similarity between simulator and real train cabin (including movement system) are the best-rated items. The model of other trains apart from the ego-train, the ability to simulate failures, and the visual/sound system received medium-high marks.

Figure 29: Degree of fidelity of several features of simulator systems

(Sample: 17 companies)

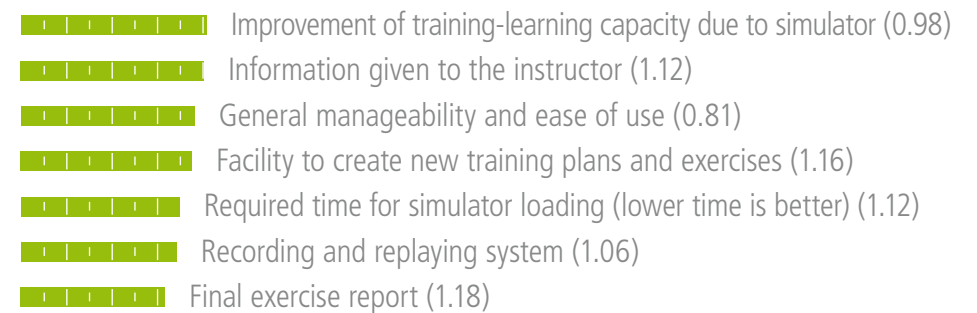


0 1 2 3 4 5 Average rating
(standard deviation is given in brackets)

Finally, the day-to-day usage of the simulators should be rated (0 = "not available", 5 = "maximal customer satisfaction"). It could be found that the operators give good marks for the improvement of training-learning capacity due to simulators and for the amount of information given to the instructor during the exercise. The less valued items are the quality of the final exercise report and the existing facilities to create new exercises. A recording system, the time needed to load the simulator exercise and the general manageability and ease of use receive medium marks.

Figure 30: Evaluation of different aspects of simulator systems

(Sample: 17 companies)



0 1 2 3 4 5 Average rating
(standard deviation is given in brackets)

5. Usage of computer-based technology



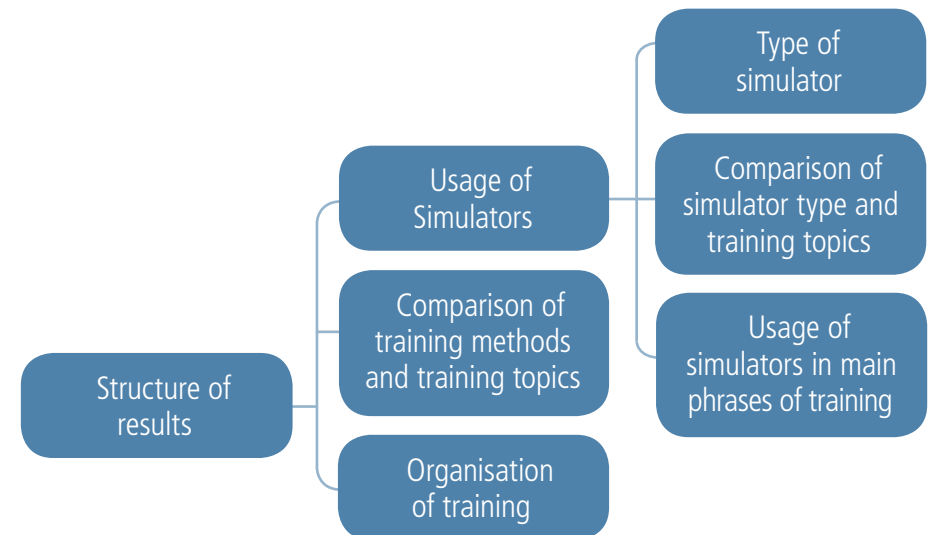
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5.1 Introduction

In the following section the benchmarking results related to different training concepts are presented (see Figure 31). After some general remarks concerning different types of simulators, several comparative tables show the extent of using simulators for a number of different training topics and in the main phases of training. Secondly, the results of a comparison of training methods and training topics are given. Finally, the organisational aspects of training in different railway companies are analysed.

Figure 31: Structure of the benchmarking results related to different training concepts



5.2 Usage of simulators

Type of simulator

Five different types of simulators were differentiated in the frame of the benchmarking interviews: (A) software interface of cab equipment, (B) part-task trainer, (C) partial cab, (D) full replica cab without motion system, and (E) full replica cab with motion system. In the following, these different types of simulation are shortly explained:

Software interface of cab equipment

A simulator using a software interface of cab equipment represents the real cab desk only on the computer screen. The trainee has to operate the train – i.e. the displayed handles, valves, buttons etc. – with standard computer components (keyboard, mouse). The display consists of a normal computer screen. This type of simulation is closely related to CBT/WBT and often runs on the same

hardware. A simulator with a software interface of cab equipment is normally used for initial training and for the training of specific operational issues of train driving.

Figure 32:
Example of a simulator with software interface of cab equipment at Metro de Madrid, Spain



TMB use simulators of the type software interface of cab equipment for advanced training and refresher courses. MdM uses this type of simulation for initial and advanced training.

Part-task trainer

Part-task trainers normally do not represent a certain vehicle. They consist of a generic panel with only a few handles, levers or buttons that are close to the original device (see Figure 33). Part-task trainers are designed for learning specific tasks, e.g. how to handle an ATP/ATC/ATO system or to learn and to apply operational rules/signalling. In most of the cases more than one part-task trainer is installed within the same room. Some part-task trainers also combine CBT/WBT and low-level simulation within one device.

Figure 33: Example of a part-task trainer at CFL



The only part-task trainers included in the analysis have been purchased by CFL, but are currently not in use.

Partial cab

Partial cab simulators represent a partial cab replica following a real vehicle. Normally, at least a part of the driver desk is modelled. Partial cab simulators are able to simulate the general vehicle logic including driving behaviour and are often also equipped with a touchscreen computer that simulates equipment located at the rear of the original cab, in the engine compartment, or outside along the train. This type of simulator does not have a closed cabin. Mostly, the visual presentation of the scenario is done by projection.

Partial cab is used by SNCB for initial training (80%), advanced training (15%) and for competence check (5%), further by VAG for initial training (65%) and advanced training (35%), by MAV for initial training (80%) and route knowledge (20%), by SNCF for initial training (35%), route knowledge (30%) and ATC/ATP (35%), and equally for initial training, advanced training and competence check by NSB and Southern. At the time of the

benchmarking study IE has planned to purchase a partial cab simulator. This should be used for initial training (15%) and equally for advanced training and competence check (85% in total).

Figure 34: Example of a partial cab simulator



(Source: NSB)

Full replica without /with motion system

These simulators represent a cab replica according to a real world vehicle (see Figure 35). They are able to simulate the general vehicle logic including driving behaviour and are mostly also equipped with a touch-screen based computer that simulates equipment located in the engine compartment, or outside along the train. If the cab replica is installed on a motion system, the driver gets an accurate feeling of the train behaviour.

Figure 35: Example of full replica cab



The training situation of being alone in a closed room is given, which helps the driver to get involved with the simulator exercise. The whole cab equipment is reproduced and it is possible to learn how to operate the vehicle and how to perform trouble-shooting in a very realistic way. The visual system consists of a projection of the tracks, surrounding, and scenery.

Full replica cab with motion system is used by DB for competence check, advanced training, initial training, and rolling stock training, by SNCB for initial training, advanced training, and competence check, and by NSB for initial training, competence check, and ATC/ATP training. SNCF uses the full replica cab for all training contents except for route knowledge, Trenitalia mainly for monitoring, and SSB for initial training, advanced training, and partially for staff recruitment. Table 5 gives an overview of the usage of a full cab replica with motion system for different training topics. Full replica cab without motion system is used by SWT for initial

training (95%), for manager competence check (2.5%), and post incident training (2.5%), by MAV for initial training (60%), advanced training (20%) and rolling stock (20%). MdM uses the full replica cab equally for initial and advanced training.

Table 6: Usage of a full replica cab with motion system for different training topics

	Initial Training	Advanced Training	Competence check	Rolling stock	Route knowledge	ATC/ATP	Other topic
DB	~10%	30-35%	50-55%	~5%	0%	~1%	0%
SNCF	75%	20%	5% ³	0%	0%	0%	0%
NSB	85% ⁴	0%	10%	0%	0%	5%	0%
SNCF	40%	15%	20%	10%	0%	15%	0%
Trenitalia	7%	3%	90% ⁵	0%	0%	0%	0%
SSB	~50%	~40-45%	0%	0%	0%	0%	~5-10% ⁶

3 Re-certification (simulator is not mandatory)

4 From September 2007 on

5 Monitoring, not competence check

6 Staff recruitment

Comparison of simulator type and training topics

The purpose of this part of the questionnaire is to obtain information on the amount of training of certain topics which is carried out using a specific type of simulator. Therefore, the companies had to match percentages with topics (initial training, advanced training, competence check, rolling stock, route knowledge, ATC/ATP, and others) and types of simulators (software interface of cab equipment, small driver desk without cab, partial cab, full replica cab without motion system and full replica cab with motion system). The main content trained on the different types of simulators differs. Type A simulators are mainly used for advanced training. Type B simulators are not used by the interviewed companies. Type C, D and E simulators are mainly used for initial training. For the training of rolling stock only simulator type E is used, for route knowledge only simulator type C and D (see Table 7).

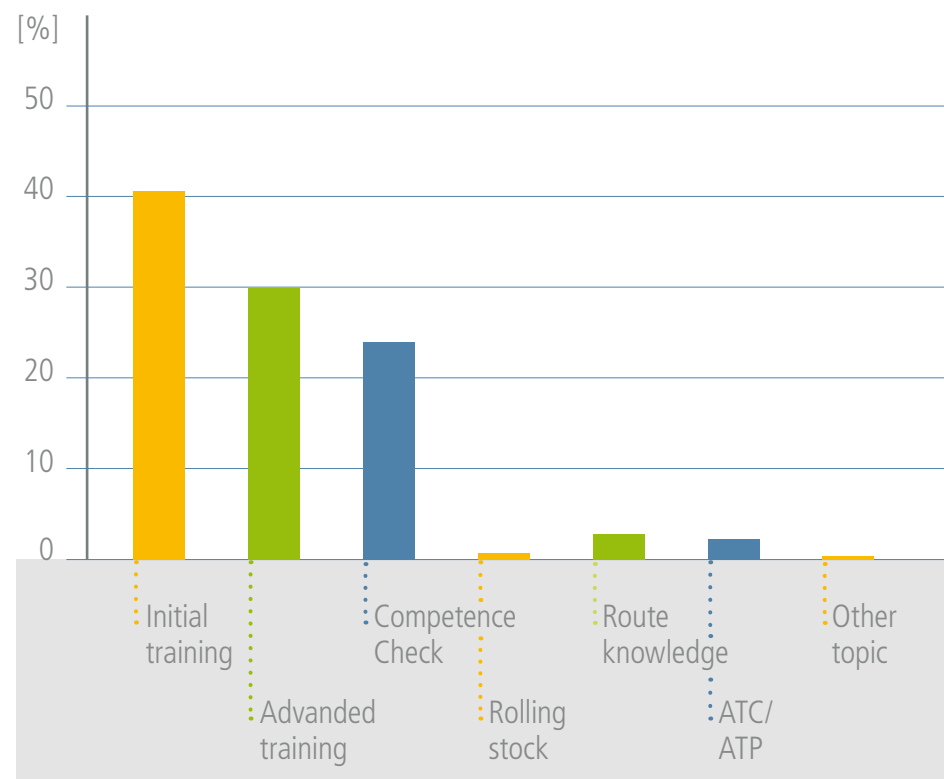
Table 7: Ratio of simulator type and training content

	Type A	Type B	Type C	Type D	Type E
Initial training	21%	0%	47%	49%	44%
Advanced training	54%	0%	26%	20%	18%
Competence check	25%	0%	15%	26%	30%
Rolling stock	0%	0%	0%	0%	3%
Route knowledge	0%	0%	6%	5%	0%
ATC / ATP	0%	0%	5%	0%	4%
Other	0%	0%	1%	0%	1%

**Figure 36: Usage of simulation
for different training topics**

(Sample: 17 companies)

In average, simulators are mainly used for initial training, followed by advanced training and competence check.



Usage of simulator in main phases of training

One major objective of the benchmarking was the analysis of the usage of simulators for initial training, advanced training, and competence check. For the following analysis the company CD has been left out due to a missing simulator. As far as MAV and IE are concerned, the given answers are estimations for the future use of the simulators as these companies are still in the process of purchasing.

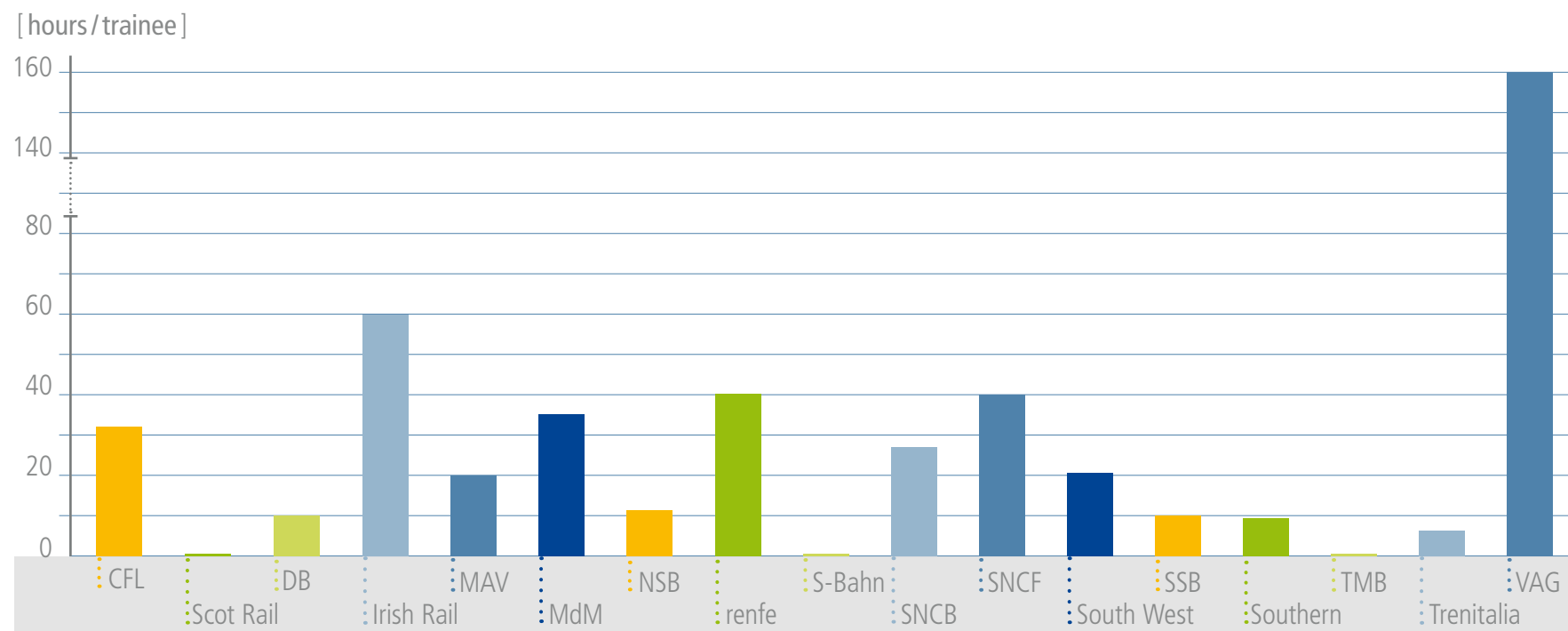
Initial Training

Within the scope of initial training there are major differences among companies concerning the usage of simulators. The average number of hours per trainee spent on a simulator in terms of initial training is approximately 30 hours. There are companies which use simulators during initial training significantly above average, for example 60 hours (IE) or even 160 hours

per trainee (VAG). There are also three companies which do not use a simulator during initial training at all (FSR, S-Bahn Berlin, and TMB) (see Figure 37).

Figure 37: Usage of simulators – initial training

(Sample: 17 companies)



Advanced Training

Simulators are used for advanced training only to a limited extent. Because of the high number of drivers in many railway undertakings and the limited resources of training hours in the simulator it is difficult to reach a higher number of hours. Renfe and TMB have the highest numbers of simulator hours in advanced training (8 hours per trainee and year). Advanced training in the simulator is not obligatory in all companies. This is because the capacity of training hours in the simulators often does not meet the requirements and not every train driver finishes an advanced training every year. Therefore, the number of hours per trainee is relatively low in contrast to initial training (see Figure 38).

Competence check

Simulators are also used for competence check, i.e. for a performance assessment of the train driver by means of a simulator exercise. As it can be seen, most of the companies use the simulator for this training topic (Figure 39). FSR has the most frequent usage of the simulator for competence checks of their train drivers. In this context, it is necessary to notice that FSR has a special procedure concerning carrying out the regular competence checks: Half of the total number of drivers has to take part in the competence check for six hours every two years. Therefore, the figure states an amount of three hours per trainee per year.

Figure 38: Usage of simulators – Advanced training

(Sample: 17 companies)

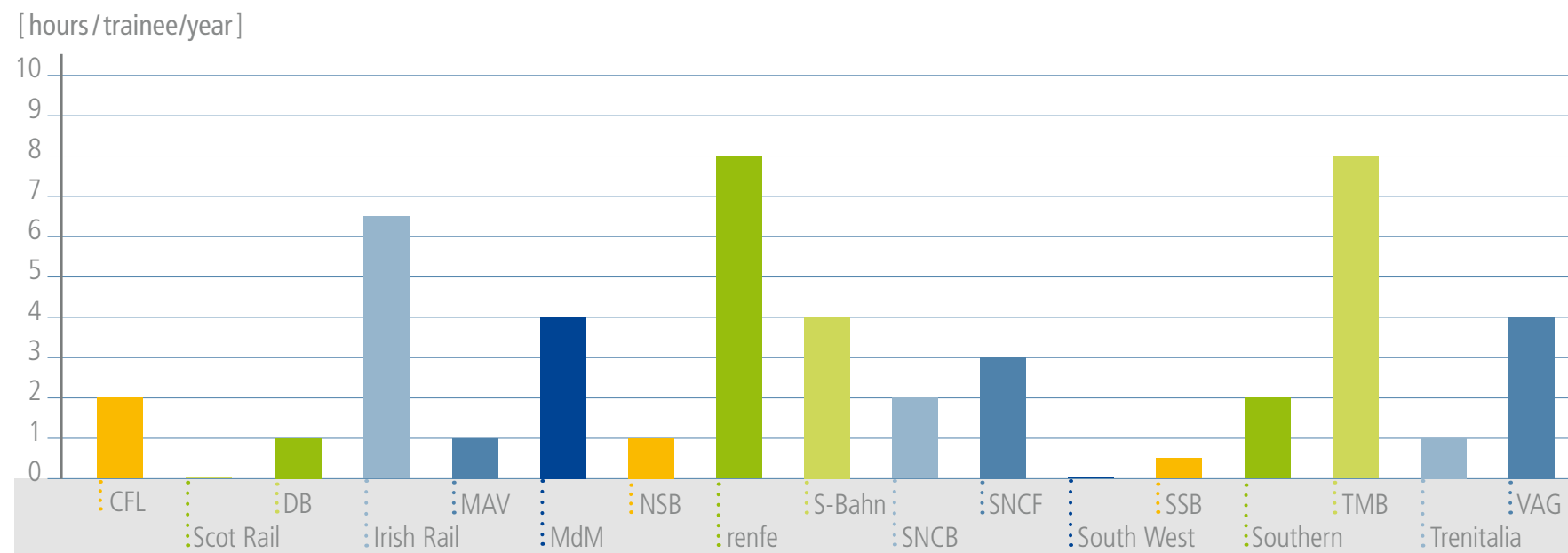
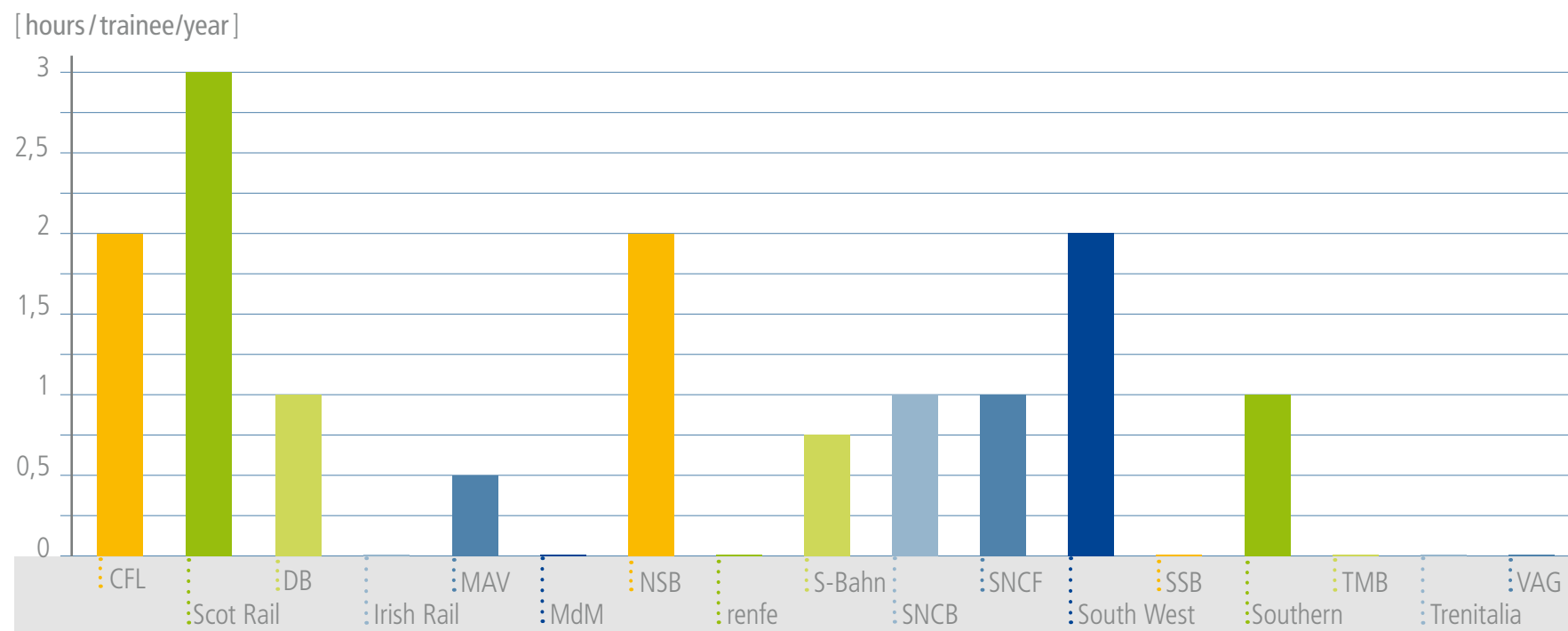


Figure 39: Usage of simulators – Competence check

(Sample: 17 companies)



5.3

Comparison of training methods and specific training topics

Another comparison that is based on the information gathered by the face-to-face interviews with 18 European railway undertakings is the analysis of training methods used for the training of specific training topics. In the following section, six training topics are analysed: (1) training of emergency situations, (2) training of driving under normal conditions, (3) training of route knowledge, (4) training of human factor issues, (5) energy saving driving, and (6) irregularities in train operations. These topics were chosen because 2TRAIN focuses on human factor contents as well as on the training of the correct behaviour in abnormal and critical situations that have the potential to be a threat to the safety of railway

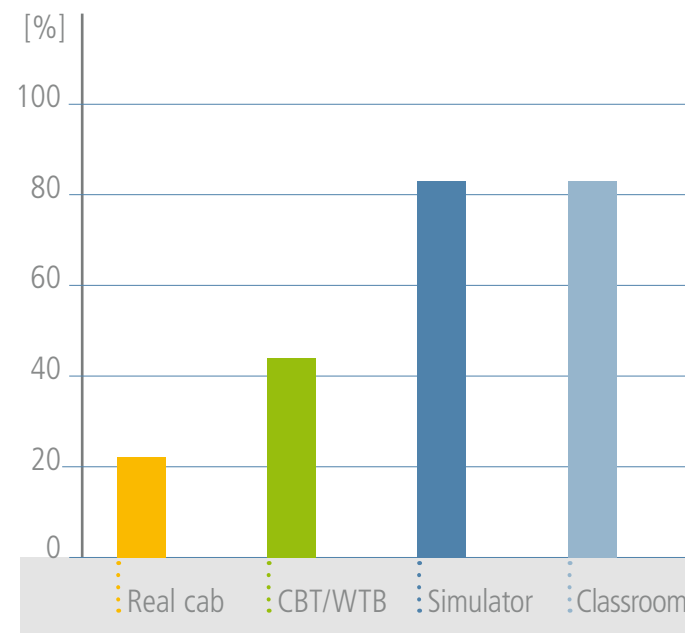
operation. The comparison is made in the following way: 100% means for example that all companies of the benchmarking interviews apply the training method for the given topic.

Training of emergency situations

The training of emergency situations practises the handling of incidents and accidents like fire in train, derailment, or collision. This training topic is mostly trained by traditional lectures in the classroom and by simulator exercises. Roughly half of the companies also use CBT/WBT modules for this training topic, whereas in only some companies the training takes place in the cabin of a real vehicle.

Figure 40: Methods for the training of emergency situations

(Sample: 18 companies)

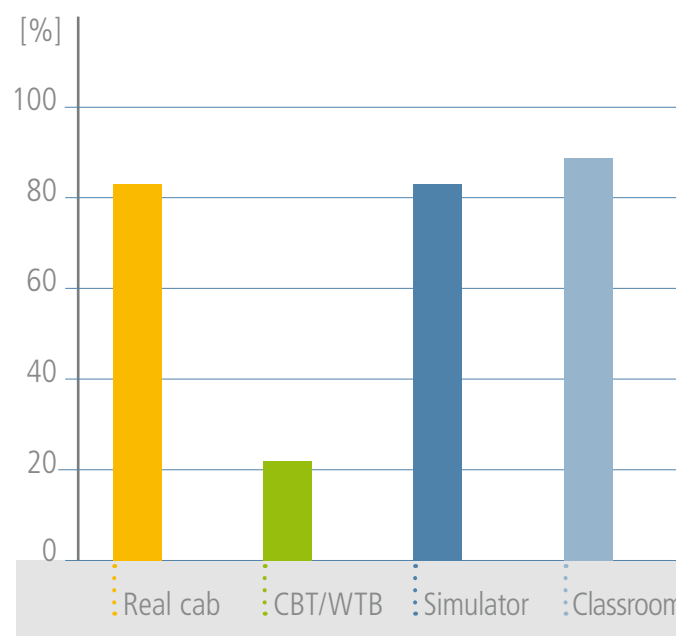


Training of driving under normal conditions

The training of driving under normal conditions involves train preparation, driving and braking, correct interpretation and handling of signals and operational rules, etc. This topic is mostly trained in classrooms, on simulators, and in the real cab. Only 20% of the interviewed companies use CBT/WBT modules. The companies S-Bahn Berlin, IE, MdM and FSR use all the methods for the training of driving under normal conditions.

Figure 41: Methods for the training of driving under normal conditions

(Sample: 18 companies)

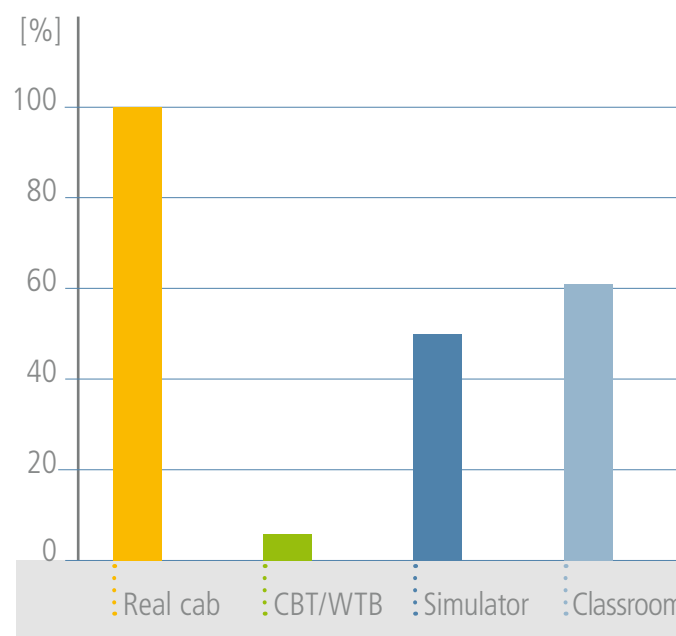


Training of route knowledge

All companies use the real vehicle for the training of route knowledge. This has two reasons: (1) nearly all companies have to follow state regulations or internal directives and (2) frequent changes in infrastructure make other forms of training inefficient. Nevertheless, some companies also use simulators for the training of route knowledge or carry out training in classrooms by using DVD or CD-ROM with recorded routes.

Figure 42: Methods for the training of route knowledge

(Sample: 18 companies)

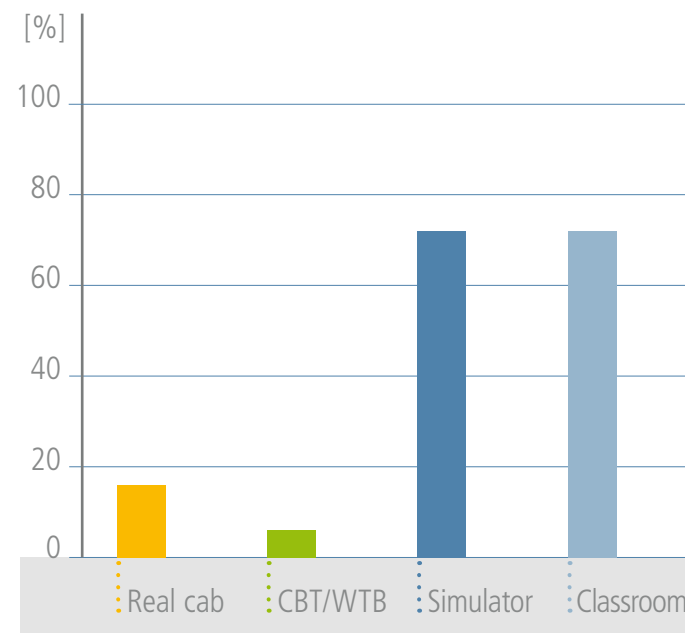


Training of human factors

Training of human factor issues includes the handling of situations with high workload and multiple tasks, decision making, and communication skills (e.g. announcements for customers, driving in stations in accordance with customers' behaviour). Training of human factors is done mainly on the simulator and in classrooms. Other methods (CBT/WBT modules or real cabin) are only used in a few companies.

Figure 43: Methods for the training of human factor issues

(Sample: 18 companies)

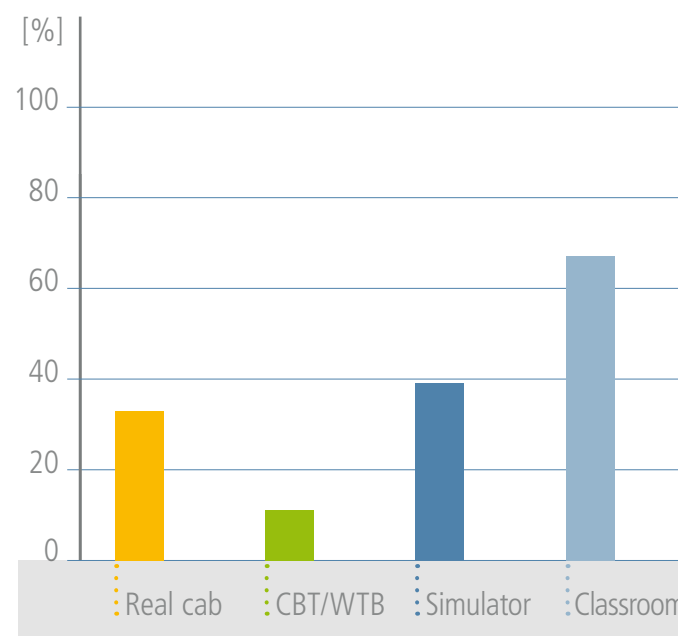


Energy saving driving

The training of energy saving driving (other: energy efficient driving, green driving) aims at reducing the energy consumption and – as a consequence – at saving money. This type of training is applied by approx. two-thirds of the interviewed companies. The most common method is training in classroom or – to a lesser extent – on simulators and in the real vehicle. CBT/WBT modules are used rather seldom for this type of training.

Figure 44: Methods for the training of energy saving driving

(Sample: 18 companies)

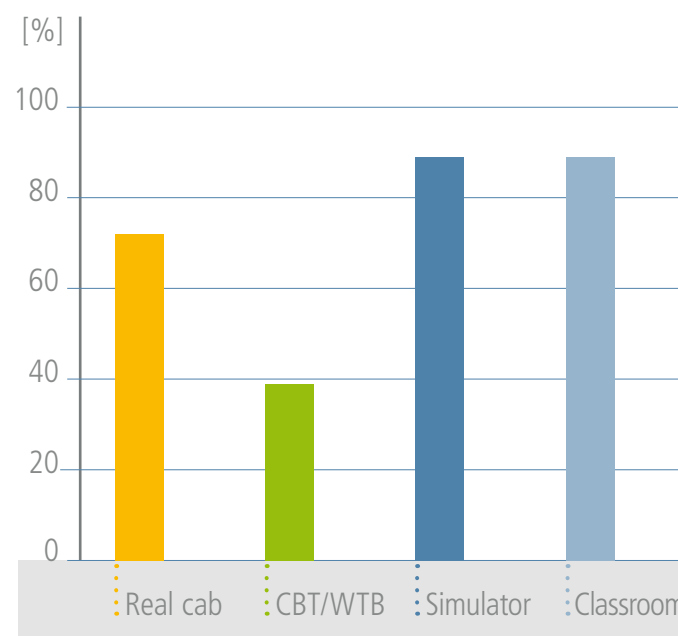


Irregularities during train operations

This topic is trained mainly by classroom lessons and simulator exercises, followed by training on the real cab and the usage of CBT/WBT modules. Some companies provide all training methods: SSB, S-Bahn Berlin, Southern Railways, IE, and DB.

Figure 45: Methods for the training of irregularities during train operation

(Sample: 18 companies)



Ratio of training content and training method

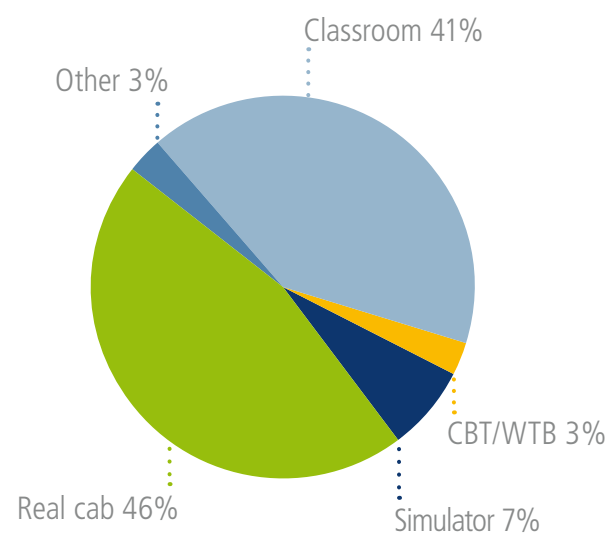
Companies which took part in the research were also compared in terms of using individual training methods (e.g. simulation, CBT/WBT, classroom, real cab) according to different training topics (e.g. initial, advanced training or competence check). For example: As an average of all companies, 46% of the overall amount/time of initial training takes place in the real cab (Note: Only those companies are included in the analysis that could provide reliable data for this comparison).

Initial training

Simulation does not play an important role in initial training. In average, just 7% of training is covered by simulator exercises. Only two companies use simulation to a higher extent: SNCF⁷ (45%) and VAG (35%). Also CBT/WBT modules are used very rarely. Only CD, MdM and S-Bahn Berlin realise more than 10% of the overall training with this computer-based technology.

Figure 46: Training methods used for initial training

(Sample: 17 companies)



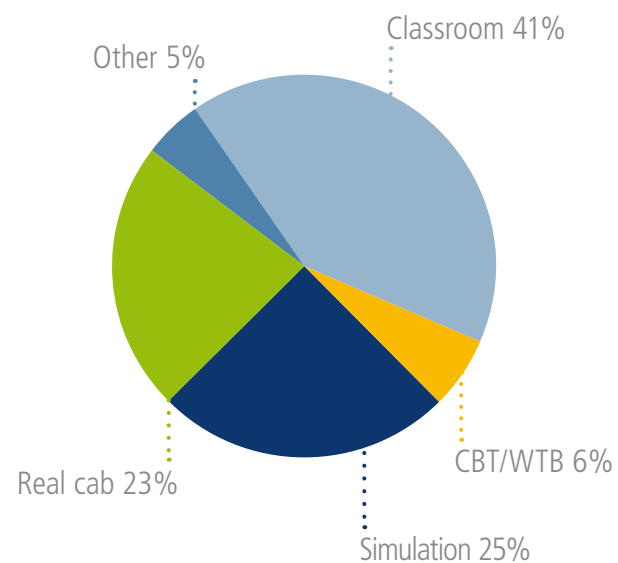
⁷ The figures of SNCF are valid for high-speed train drivers, i.e. for trainees who are already experienced drivers on “standard” trains.

Advanced training

The distribution concerning the usage of simulation in advanced training shows another picture. In average, the simulators are used in 25% of the overall training. It is important to mention that six companies do not use simulation for advanced training at all. The ratio of simulator training at VAG is 80%, at Renfe, SNCF and TMB 50%.

Figure 47: Training methods used for advanced training

(Sample: 15 companies)



Competence check

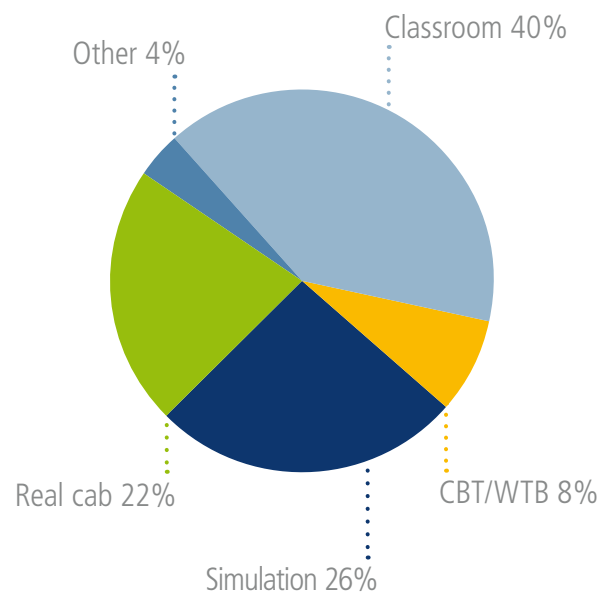
The ratio of training methods used to check the competence level of a train driver is very similar to the ratio that was found for advanced training.

The companies use at least two different methods, DB, NSB and Trenitalia even a mixture of four methods.

At Trenitalia the competence assessment is done as a continuous monitoring process including the analysis of the train data. MAV and Southern realise competence assessment mainly in the classroom (80% and 94%).

Figure 48: Training methods used for competence check

(Sample: 11 companies)

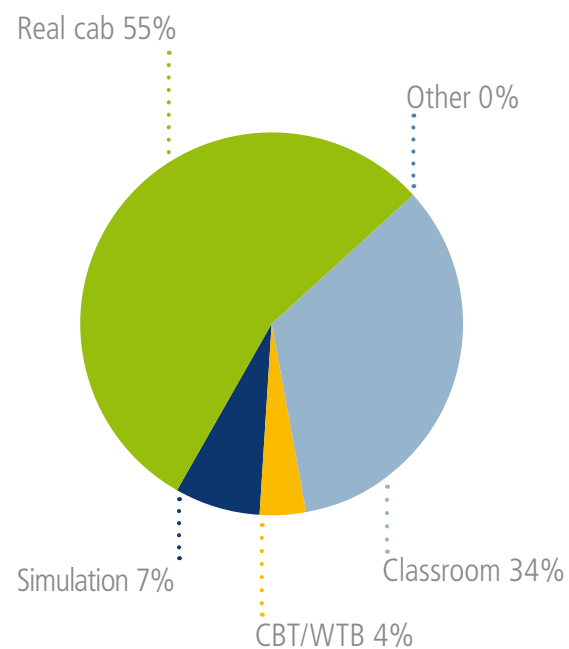


Rolling stock

For the training on rolling stock most companies use a combination of training on the real cab and classroom lessons. Only at three undertakings specific CBT/WBT modules are available. Only SWT and VAG cover a significant portion of the overall training with simulation (both about 30%).

Figure 49: Training methods used for rolling stock training

(Sample: 12 companies)

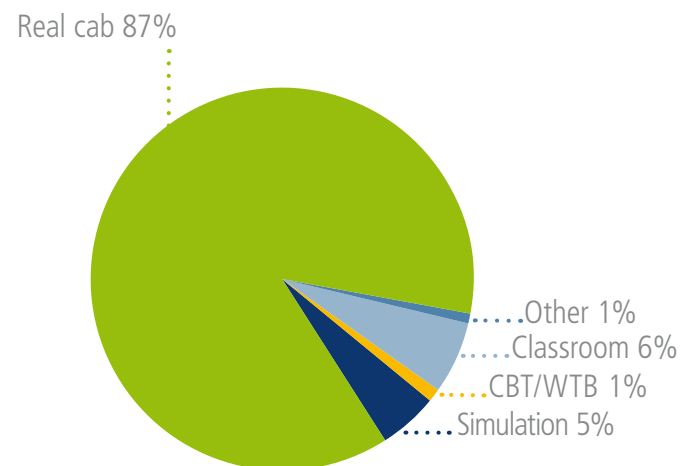


Route knowledge

As mentioned before, training on the real cab is the first choice for the acquisition of route knowledge. Five companies use only this method. The other training methods just play a supportive role.

Figure 50: Training methods used for training of route knowledge

(Sample: 14 companies)

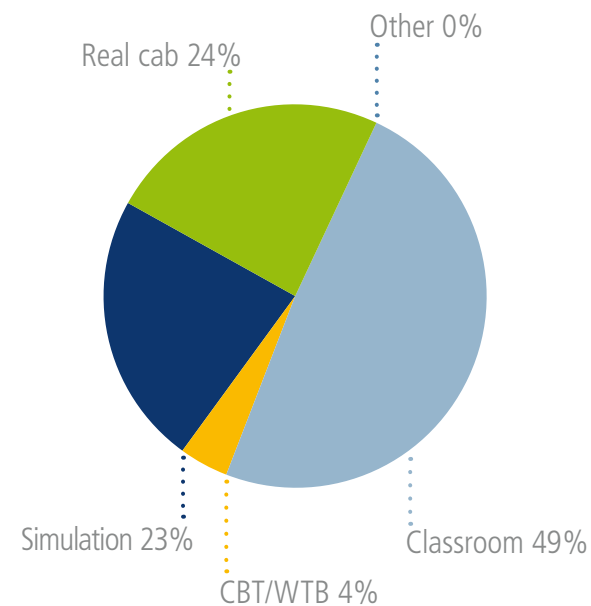


ATC/ATP

Eight companies provide information about the distribution of training methods and ATC/ATP training. As seen in Figure 29, nearly 50% of this training topic is acquired in classroom lessons. All companies use at least real cab or simulation as a second method. Only DB and SNCB use CBT/WBT modules for this topic.

Figure 51: Training methods used for ATC/ATP training

(Sample: 8 companies)



5.4 Organisation of training

The final part of the benchmarking questionnaire is a part devoted to the organisation of training and focuses on such questions as the distribution of training centres, different methods of competence assessment, different methods of storing training results, and many other processes which are related to the organisation of the training. This part is focused on both training methods: simulators as well as CBT/WBT modules. In many cases it can be found that the organisation of simulator training differs from the organisation of CBT/WBT training. The following chapters cover: (1) organisation of training, (2) development of training content, (3) competence assessment, and (4) feedback of the companies concerning their own training methods and training technologies.

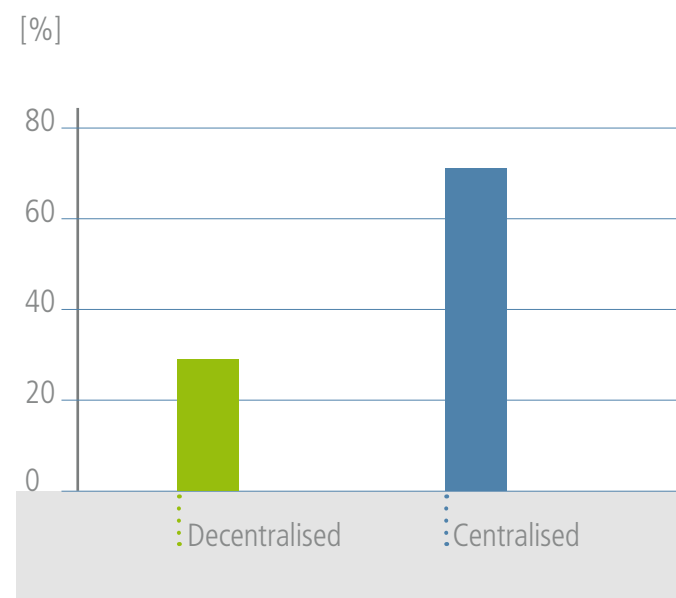
Localisation of the training centre

The interviewed railway companies reported interesting variations concerning the degree of centralisation of training. Whereas most companies use centralised simulator training centres, CBT/WBT training is often decentralised. Nevertheless, all Spanish companies taking part in this research (Renfe, TMB and MdM) are among the companies which have decentralised systems of simulator training. They are also joined by two other companies (DB and SNCB) (see Figure 52).

The interviewed railway companies report that simulator training is normally conducted by internal instructors or instructors from the company training department. It is unusual to charge a completely external company or to combine these approaches.

Figure 52: Localisation of training centres

(Sample: 18 companies)

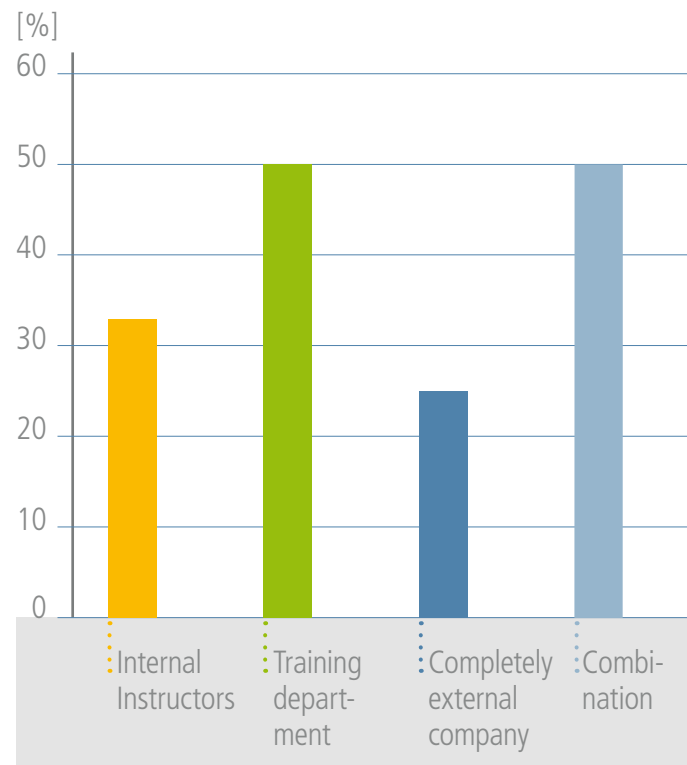


Training development

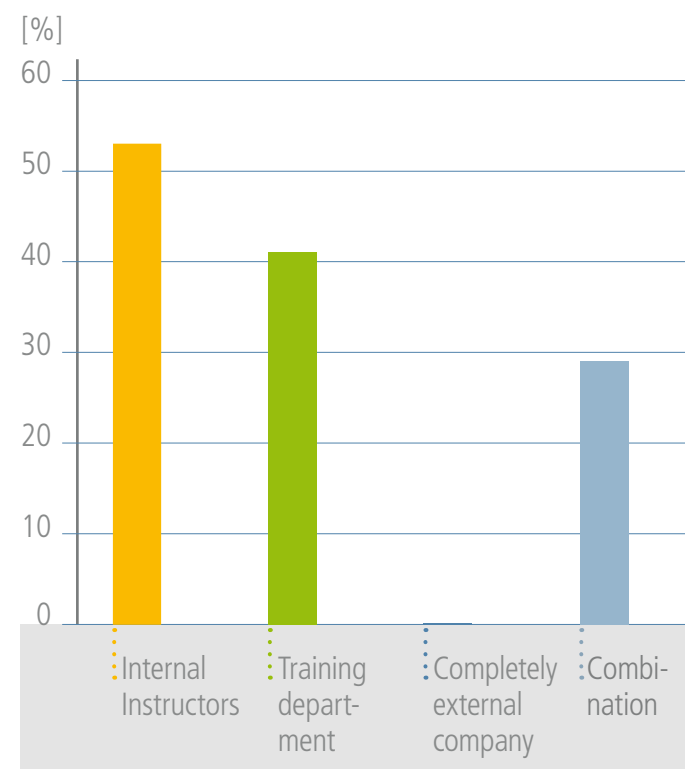
Regarding the development of new training modules for simulator or CBT/WBT it is interesting to observe that for simulators, training development is mostly done by internal instructors, whereas CBT/WBT modules are often co-developed by all partners involved (internal instructors, instructors of the training department, external company) (Figure 53, Figure 54). None of the interviewed companies commissions an external company with the development of simulator training modules.

Figure 53: CBT/WBT training development

(Sample: 17 companies)

**Figure 54: Simulator training development**

(Sample: 13 companies)



Assessment

Another part of the interview is devoted to the method of competence and performance assessment used on simulators and CBT/WBT. The interviewed companies were asked if they use CBT/WBT knowledge tests or simulator exercises with specific events in order to assess the competence and performance of the trainees. The most frequent method of competence assessment is using a simulator. But CBT/WBT knowledge tests are also used. Almost all companies use some kind of computer based archives to store the data and results obtained in the course of training. Except for TMB and VAG which are considering the method of storage, all companies decided to use a specific type of computer database which is able to store the data in the course or after completing the training. Another issue during the interviews was about the selling of free training capacity of the simulator or CBT/WBT to external companies. Six out of 18

companies (DB, SNCB, Renfe, NSB, SNCF, and S-Bahn Berlin) do sometimes sell free training capacity.

Improvements and shortcomings

The last part of the interviews was devoted to the shortcomings and failures which the companies would like to remove in the near future. Companies were asked for any evaluation studies conducted in the past. Such studies should clarify if the training is interesting and motivating for the trainee and if the training achieves the expected results in terms of knowledge transfer, behavioural change, skills and competence development. Besides the fact that some companies have introduced a regular feedback instrument (paper-pencil) asking for the trainees' acceptance of the computer-based training sessions, no company evaluates the training effects in a systemic and standardised way. Each company states certain insufficiencies regarding the operation, maintenance and development of simulator training. The answers can be divided into (1) technical and economical shortcomings, (2) shortcomings related to

the assessment capabilities, (3) feedback given by the trainees, (4) feedback given by the labour unions, and (5) the intention of future improvements.

The given answers imply that it is difficult to maintain the simulator at the level of the real system (according to changes affecting the infrastructure or the rolling stock) as implementing changes in the simulation is often cost expensive and time consuming and can only be done by the manufacturer. The realisation of a generic driver's cab and a generic infrastructure is suggested as a reasonable solution to achieve a higher flexibility in terms of developing new exercises. Other comments respond to the quality of post-run analyses as there is not enough feedback and assessment data for the instructor. A simpler scoring report with an option of focusing on errors could be one solution. At some training simulators an automated objective assessment system is totally missing. As a consequence, the use of objective performance markers for the assessment procedure and a

connection of the assessment database with the company's information system are proposed. Concerning the trainees' feedback, some drivers ask for more sessions on the simulator and demand for an immediate re-training after an incorrect action. The fidelity of simulation should be as high as possible. Due to a missing full motion system, some existing drivers are not keen on simulators as the sensation of braking is limited. The feedback given by labour unions and staff councils is inconsistent. At some companies an agreement with the staff council has been settled not to use the simulator for the surveillance of train drivers. At other companies, unions do not allow the detailed performance check by using objective assessment data. Furthermore, simulator sessions can only be attributed as additional training and should never reduce the amount of conventional methods. Other companies quote that the acceptance and compliance are quite high. Good experience was made with the involvement of the labour unions from the beginning on

as part of the simulator steering group. Asking for future improvements and planning some companies argue for an intensified use of simulation in the course of initial training, for training sessions focused on the distraction of drivers in critical phases, and for implementing cross-border training on partial cab simulators. Other companies would like to increase the number of simulated engine types and realise a higher number of small desk simulators aiming at a whole fleet of simulators.

This is the list of the main shortcomings mentioned:

- Difficulty in keeping the simulator up-to-date (e.g. concerning the real line and its characteristics)
 - Missing database and insufficient assessment system
 - Relatively high costs per trainee
 - Expensiveness of purchasing a simulator with a high number of realistic lines
 - Software problems and bugs
 - No possibility of replaying previous situations
-

-
- Relatively small number of training events that can be simulated
 - Problems with motion system
 - Unsatisfying simulation of rain

Summary table

The following table summarises the main data about the simulator training systems and shows the main characteristics of the training systems in each company: localisation of the simulators, responsibility for the training development and for the training regulations, usage of the simulators for competence assessment and scheduling of this assessment, storage of training results, usage of competence management systems, and evaluation of acceptance or learning effects.

Table 8: Summary Table

Company	Location of SIM	SIM exercise development	Regulation of training	Competence assessment	Assessment schedule	Storage of results	CMS ⁸	Evaluation
CFL	Central	Training department	not determined	YES	mandatory (after incident) voluntary (2 hrs/year)	YES (Protocol sheet)	NO	NO
DB	Decentral	Internal & Customers	national + company	YES	mandatory (1-2 hrs/year) voluntary (after initial training, after incident)	YES (Protocol sheet)	NO	Learning effects (2004) Acceptance (2005)
FSR	Central	Internal	mainly national	YES	mandatory (after initial training, regular)	YES (Protocol sheet)	NO	NO
IE	Central	Internal	mainly company	YES	mandatory (after initial training, after incident, regular (6.5 hrs/year))	YES (SIM database)	NO	NO
MAV	Central	Training department	national	YES	mandatory (after initial training, regular (0.5 hr/2 yrs)) voluntary (after incident)	YES (SAP authority tool, MELIS)	YES	NO

Company	Location of SIM	SIM exercise development	Regulation of training	Competence assessment	Assessment schedule	Storage of results	CMS ⁸	Evaluation
MdM	Decentral	Internal & External	national (light rail) + company (metro)	NO	-	NO	YES	Acceptance (continuous)
NSB	Central	Training department	national + company	YES	mandatory (after initial training, regular (4 hrs/2 yrs))	YES (Protocol sheets)	NO	Acceptance (annual feedback)
RENFE	Decentral	Internal & External	national	Not yet	-	YES (SIM Database)	NO	Acceptance (continuous)
S-BAHN BERLIN	Central	Internal	national + company	YES	mandatory (after initial training, after incident, regular (0.75 hr/5 yrs))	YES (Protocol sheets)	YES	NO
SNCB	Decentral	Training department	national + company	YES	mandatory (after initial training (3hrs), voluntary (after incident, regular (1 hr/3 yrs))	YES (SIM database + protocol sheet)	NO	Acceptance (2004)

Company	Location of SIM	SIM exercise development	Regulation of training	Competence assessment	Assessment schedule	Storage of results	CMS ⁸	Evaluation
SNCF (high speed)	Central	Internal & Training department	company	YES	mandatory (after initial training), voluntary (after incident, regular)	YES (SIM database)	NO	Acceptance and Learning (2007)
Southern	Central	Internal & Training department	national + company	NO	-	YES (SIM database)	NO	Acceptance (2006)
SSB	Central	Internal & Chief operating manager	national + company	NO	-	NO	NO	NO
SWT	Central	Internal	national + company	NO	-	YES (SIM)	NO	NO
TMB	Decentral	External & Internal	national + company	NO	-	NO	NO	Acceptance (continuous)

Company	Location of SIM	SIM exercise development	Regulation of training	Competence assessment	Assessment schedule	Storage of results	CMS ⁸	Evaluation
Trenitalia	Central	Internal	national	YES	voluntary (regular (1 hr/year))	YES (Personnel book)	NO	Acceptance (continuous)
VAG	Central	Internal & Chief operating manager	national + company	NO	-	being discussed	NO	NO

⁸ Content management system

6. Training concepts in selected companies



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6.1 Introduction

18 companies with almost 18 different approaches concerning the usage of simulators or CBT/WBT modules for training of train drivers took part in the benchmarking process. Among these companies, one company does not possess a simulator but is seriously thinking of purchasing one in the nearest future (CD), two companies are currently in the process of implementing simulators (MAV and IE), and 15 companies already have several years of experience in operating at least one simulator. CBT/WBT modules are used in 13 out of 18 companies. In the following, individual companies state their reasons for implementing simulators into the training system, summarise the main purpose for using simulator exercises or CBT/WBT modules and add other interesting information, e.g. plans for the future. Where available, pictures taken at the training centres illustrate the different solutions of the different companies.

6.2 Ceske drahy

CD does not currently operate any type of simulator. Other e-learning tools are used to a limited extent (e.g. animated flow charts describing some functions and information about trains, traction, and technology).

Main reasons for purchasing the simulators

As it is planned to widen the national and international operations in the near future, it is necessary for CD to invest in simulator solutions and to build up a computer-based training system. The main reason for purchasing the simulators is to enhance the training facilities. The training system of CD is based on classroom and real-cab training. New simulators could allow more efficient training and also save financial resources.

The second reason is that without simulators CD loses their employees' capacities because the training system is specifically based on real cab training. The training

includes a two driver system (where one of them is an experienced driver – minimum 5 years experience).

Main application

As CD wants to achieve safer railway operation it is expected that the simulator will train drivers to deal with unexpected situations and emergency scenarios. Therefore, it is important that the simulators should be able to assess the reactions of the trainees and to provide a detailed exercise report. The main application of CBT/WBT modules is to train drivers in the frame of initial training as there is a clear need to customise drivers to operate with all the rules included in national and company directives. CD expects to train these situations by means of CBT/WBT modules because the training simulator should be used for advanced training.

Additional comments

At present, CD is trying to accomplish a new project which focuses on the production of a new simulator in cooperation with a Czech producer of locomotives and a Czech scientific centre. The main system to be constructed is derived from a new type of electric traction locomotive (No. 380). It is multi-system traction based on European driver's desk. It is expected that this simulator will be used in the training of drivers in interoperability operation and drivers who operate on high speed trains.

6.3 Societe Nationale des Chemins de fer Luxembourgeois



CFL has purchased a complete system that consists of one full mission simulator, ten part-task trainers and CBT modules. The system simulates the engine type CFL 3 000. This system was delivered by KMW in 2001. The last update was made in 2005. In the course of this update, 35 kilometres of generic tracks with French infrastructure equipment were added.

Main reasons for running the simulation system

In 1997, some serious accidents happened on the Luxembourg network. The main causes for these accidents were mistakes made by the train drivers. Therefore, the education and advanced training should be optimised. This objective should also be reached by the use of driving simulators.

Main application

The simulator was intensively used for initial training in 2003/2004. No train drivers have undergone training in the last two years and training is unlikely to take place in the next few years. The initial training comprises the education on the network of Luxembourg, Belgium, and France as drivers of CFL operate in France (Luxembourg – Basel) as well as on some lines in Belgium. At the moment, there are no train drivers in service on the German network. There are lots of changes in the railway system including changes in regulations, rolling stock and training contents. Therefore, the PTT systems and the CBT/WBT modules are not up to date and have not been used for several months. Drivers from Belgium are going to come to Luxembourg in 2007 for the purpose of training on the Luxembourg network.

Additional comments

There will be two operational departments at CFL. CFL (passenger trains) and CFL Cargo (freight trains). This separation will be realised step-by-step in the near future. A training centre will also be constructed. At this point it has not yet been decided which of these parties will run/own the simulator in the future. Today, CFL would prefer a system that is more flexible and a motion system would no longer be essential.

Figure 55: Simulation site at the CFL training centre in Luxembourg



6.4 Deutsche Bahn

In 1996 DB started to use simulators for train driver training. At present 17 full-mission simulators are in use, covering high speed/long distance, local and freight train rolling stock. The simulators are located at eleven training centres across Germany. The largest one at Fulda has five simulators and with two simulators the centre at Munich is the second largest. Each of the other nine centres is equipped with one simulator. Another simulator is owned by DB Academy in Potsdam and is used exclusively for management training. The supply of the simulators' first series (12) was shared between EADS Germany (6) and Krauss-Maffei-Wegmann (6). The second series (5 simulators) was supplied by Krauss-Maffei-Wegmann, but EADS Germany did act as a subcontractor. In 2006 the first simulator (for ICE 1/2, delivered in 1996) was upgraded with new hard- and LINUX based software.

Due to the usage of new PC-based CGI technology and the replacement of the former CRT by a D-ILA projector, the visual system in particular did receive a significant enhancement. DB also has CBT/WBT modules which are used for the training of knowledge of rolling stock and ATP/ATC systems, as well as CBT and WBT modules used for yearly advanced training. At present, DB has a total of 19 CBT/WBT modules in use for driver training.

Main reasons for purchasing the simulators

After its privatisation DB did purchase a lot of new rolling stock and the drivers had to be trained to drive these trains and locomotives. So the main reason for purchasing the simulators in the 1990s was conversion (rolling stock) training but from the beginning the simulators were also designed to cover training for operational procedures, and so on. After a major accident happened in 2000, a significant change in the simulator usage followed in 2002.

From the year 2000 onwards every driver employed at DB has had to pass a 1-hour competence check at the simulator every year.

Main application

With approximately 21 000 hours per year at present the competence checks are the main application of the simulators at Deutsche Bahn. Furthermore, during the initial training to become a train driver at DB the simulator is used for four hours in two training modules. The first module includes initial training and is focused on driving under normal/abnormal operational conditions. The second one is used as a preparation for the final exams. Additionally the simulators are still in use for conversion training (especially for the ICE trains), advanced operational training, training for ATP/ATC systems and training for driving in low-adhesion conditions. Between 2003 and 2005 a company wide training programme to reduce energy consumption took place.

Part of this programme was also a 1-hour simulator ride. Finally, the simulators are also in use for human factors training, especially for coping with stress and for decision making.

Additional comments

DB has about 21 000 train drivers and 17 simulators. In the future no significant changes in the strategy of training on simulators are expected. Regarding technical issues, over the next few years it is planned to equip all of the simulators with new hard- and software as has already been done with the ICE 1/2 simulator.

Figure 56: Photos from DB simulator site



6.5 First Scot Rail

First Scot Rail (FSR) has two driving simulators, although FSR does not have any CBT/WBT modules. The simulators were delivered by Sydac for the Class 170 DMU and Class 334 EMU. They are simulators for passenger trains and were delivered early in 2007.

Main reasons for purchasing the simulation systems

The main focus in using the simulators currently is competence assessment which everybody with a driving licence has to undergo (including driver standards managers, assessors and driving instructors). The simulators are located at Glasgow Central Station. The impact is that some drivers have to stay overnight in hotels in Glasgow for training. The competence assessment process currently works on a two yearly cycle. The business case was that the simulator is self-funding by saving the driver team manager's time (as he is no

longer involved in the process) and the train driver's time which he would have spent one-to-one with his manager. Other competencies now tested on the simulator would have involved him spending more time with drivers capturing the data. However, the driver manager remains responsible for managing the on-going competence of the drivers, supported by the simulator, but also using other methods of evidence gathering. The simulators are also used for drivers returning to work after sick leave. The feedback from the drivers is very positive. Feedback questionnaires go to the driver's team manager. The trade unions are also supportive, probably due to the fact they were involved from the beginning of the project as a part of the steering group.

Main application

The simulator runs on more than one computer on the local network and it is a full cab replica with original control, keyboard and touch screens. The simulators do not have any motion system. There are two generic (geo-typical) tracks, each of 70 kilometres long. The competence check is being provided to 450 drivers, plus approximately 30 Managers for six hours per person each year. Post-qualified drivers attend simulator session three times over two years (18 hours) for competence checks and support.

Additional comments

FSR has 880 train drivers and 30 in preparation. There is currently no use of the simulators for either initial training or advanced training, although this is under review. A trial to explore the initial integration into basic driver training starts in September 2007. There are several aspirations for other uses of the simulators (for research

on hearing aids for drivers or research on motion seats).

The FSR uses DVDs for route learning of the routes, which is available for use as "own time learning". They also intend to use CBA/WBT in the future for competence assessment. This will start in autumn 2007.

Figure 57: Photos from FSR simulator site

(Source: Sydac)



6.6 Irish Rail *irishrail.ie*

Currently, IE (Iarnród Éireann) has no driving simulators in operation. However, this is still in development with the intention to procure. Many of the exact characteristics of the future driving simulator are unknown (other than that it will be focused on a passenger train). This will represent the first driving simulator in the company. It is planned to use the simulator in parallel with other training methodologies. IE is currently planning to introduce CBT/WBT modules, for example. There is an expectation that the simulators will be used over two days per trainee for both advanced training and competence check together, every two years – hence 6.5 hours per trainee per year allocated across each of those two categories. Both the simulators and the computer-based training system will be located in two specialised centres which are Inchicore (about 75% of training capacities) and Portlaoise (the rest of the training capacity).

Main reasons for purchasing the simulators

The main reason for purchasing the simulators is to improve the quality of the training outcome and its transferability back into the workplace. It is expected that the simulators will improve training effectiveness and efficiency (duration). They are seen as being a key lever to improving the skills and abilities of train drivers. IE wants specifically to focus on train driver behaviour, in particular, competence in communications and decision making. The simulator will be used to observe actual behaviour during the emergency situations. It is expected that the simulator will help also with training of energy saving driving and other types of driving, such as low adhesion.

Main application

It is expected that the simulator will be used for all types of training (from initial to advanced training). There are a further two days advanced / competence check training, but the intention is that this will be a conventional

classroom-based event – a blended learning/competence management approach, complementary rather than alternative. In the case of preparation of drivers, it is proposed to use two simulators desks to train drivers in shunting. The system is focused on rules of shunting (which train will move first in a shunting context). The content of simulator training will be strong multilevel and it will include all of the most important abilities of training (real time simulator, question/answer, communication, co-operating with other staff). The Irish train operating company has about 550 train drivers, operating on around 2400 kilometres of track (counting 10 kilometres of double line as 20 kilometres of track). IE will acquire around 360 kilometres of visual database with the simulator system (some electrified, some MACLS and some semaphore).

6.7 MAV Magyar Allamvasutak



MAV has about ten CBT/WBT modules in the SAP LSO management system and is in the process of purchasing a simulator. The simulator will be delivered in September 2007 by CORYS T.E.S.S.

Main reasons for purchasing the simulation systems

MAV has wanted to buy a simulator for many years, the main reasons being: (1) to train emergency situations only possible with a simulator and (2) training with a simulator is more effective than classroom training.

A simulator was ordered when the financial conditions for purchase were achieved. The simulator will be used mostly in the field of initial training (80%) or route knowledge (20%). Its location will be Budapest. The assessment method should be combined with CBT/WBT tests.

Main application

The simulator represents the route Budapest Kelenföld-Győr. The simulator represents the real time simulations and enables communication with other drivers/trainees. The simulator runs on more than one computer in a local network. It also communicates with the SAP database. The simulator includes a full replica cab with a vibration seat and two mobile simulators with a simplified driver desk close to original. There is one realistic track with a length of 125 kilometres. The simulator will be used in initial training for 20 hours per trainee, in advanced training for 1 hour per trainee/year and in a competence check for 0.5 hour per trainee over a period of two years.

Additional comments

MAV is a public railway transport company of Hungary. It currently operates only passenger trains, but provides train drivers to freight companies (MAV trains all railway personnel in Hungary).

Figure 58: Photos from MAV simulator

(Source: Corys T.E.S.S)



6.8 Metro de Madrid



The Metro de Madrid S.A. (MdM) has approximately 6 000 employees including about 1 600 regular train drivers and on average about 15 new drivers and 15 experienced drivers in training. The network that is operated by this company has an overall length of 310 km. For training, four simulators and two CBT/WBT modules are used. MdM is going to have three new simulators during 2007-2008. CBT/WBT modules were delivered by Grupo Garben in 1996 and are used for Metro (2000 CAF and 5000 CAF). The last modification was in 2004. The main improvement was "Network connection". The upgrade was developed by Atos Origin. Two simulators (7000 Ansaldo Breda and 8000 CAF) were manufactured by INDRA and CITEF, delivered in December 2002 and have been used only for Metro. The next three simulators Citadis, 3000 and 9000 were developed by the same company – CITEF. Model Citadis light rail (Alstom)

is used for passenger trains while 9000 (Ansaldo Breda) and 3000 (CAF) models are used for Metro. All simulators are without a motion system and all driving functionality subsystems are simulated. Simulator and CBT/WBT training is distributed over the whole city of Madrid.

Main reasons for purchasing the simulators

Firstly, simulators can be used to teach a great number of trainees in a short time, even before real rolling stock is available. Secondly, learning in a simulator is safer than learning in the real train. There are also situations that can not be simulated in the real train.

Main application

In the frame of initial training the simulator is used for 35 hours per trainee, in the frame of advanced training for four hours per trainee and year (but not every driver attends the course of advanced training every year). Simulation is used for almost every training topic (e.g.

basic technical knowledge, operation of train control system, route knowledge) as well as for specific topics (e.g. training emergency situations, customer oriented behaviour, human factors). Concerning performance assessment, the CBT/WBT can make an assessment but its results are not decisive. In the future, simulators will have similar assessment capabilities to the CBT/WBT.

Additional comments

In 2007 Metro Madrid has increased its network extensively and for that reason this company has a lot of drivers in training. External customers do not use simulators/CBT due to its specific design. Sometimes a simulator is used for training subcontractors. MdM is planning to widen the simulator training by creating smaller desk simulators and distributing them around the city of Madrid. They do not have plans to purchase any new simulators because nowadays all trains (excluding 6000 series) have a simulator or a CBT module.

But they want to connect the simulators to the company's information system – SAP. The opinion of the labour unions and staff council is that usage of a simulator can only be seen as an additional task of the formation, classrooms or practice should not be reduced.

Figure 59: Photos from MdM simulator site



6.9 Norges Statsbaner

In 2002, NSB purchased five partial-cab simulators and one full-cab simulator from CORYS T.E.S.S. The systems were delivered in 2004. All six simulators represent the same rolling stock type, the EMU class 72. The full-cab simulator uses the same software as the desk-simulators, only an additional module to handle the motion system is added. The five desk-simulators are controlled by two instructors, working at one control stand for the five simulators. The full-cab simulator has its own instructor desk.

Main reasons for purchasing the simulation systems

The usage of simulators is a very efficient way in which to implement a standardised advanced driver training. Additionally, the simulators were purchased for training the drivers to handle the Norwegian ATP-system (called "ATC").

Main application

Every two years the NSB drivers come to the training centre to perform a 20-hour training programme. Part of these 20 hours is also a 4-hour session on the simulator (partial-cab/desk-trainer), combining training and competence check. Broken down to a yearly calculation, this means two hours per year and driver. After two years all NSB drivers and conductors have passed the training and then a new training period starts with different content. The next time this will happen in September 2007 and then also some new training topics will be introduced (see below).

Therefore, at Drammen NSB operates a training centre with various facilities to train drivers and conductors. Beneath the six simulators there are also class-rooms and an outside training area, where e.g. to earth the catenary by using a real size model and some evacuation procedures in cases of emergency (during which an old EMU is used) is practised. During these three days

the train drivers have in total four hours on the simulator. The simulator runs are primarily for training, but in case the driver makes a significant failure this will be recognised and some special training will be performed later. So the simulator runs are a combination of training and assessment. From September 2007 on the 20-hour advanced training programme, a human factors training will be added that deals with the distraction of the driver during an emergency situation. Additionally, for technical rolling-stock training the simulators (mainly the full-mission simulator) will be used in the future. Furthermore, it is planned to also use the simulators for training on environmental driving, but this project is still at a very early stage.

Additional comments

The basic education to become a train driver in Norway is provided by the state as a vocational training at the "Norwegian Railway Academy". NSB trains only drivers

who have passed this vocational training and who joined the employment of NSB. In addition to this NSB-specific training some of the vocational training is also done on order by the "Norwegian Railway Academy", because NSB does not have their own simulator.

Figure 60: Photos from NSB simulator site

(Source: NSB)



6.10 Red Nacional de los Ferrocarriles Espanoles *renfe*

RENFE has five CBT modules and three simulators. The CBT modules were manufactured by internal experts. The CBT was established in 2003 and includes training modules for passenger trains and high speed trains.

Main reasons for purchasing the simulation systems

The main reason for the development of CBT modules was the fact that CBTs are absolutely necessary for the training of regulations. One advantage is that the simulators simplify and shorten the overall training. The first simulator was designed for learning circulation; the newer approach is for driving. The training on the simulator is given to a group of drivers. The simulator is used for initial training (40 hours per trainee) as well as for advanced training (8 hours per trainee/year).

Main application

Some of the CBT modules run on only one computer using the internet browser. They are programmed in Java, Flash, etc. RENFE is currently finalising a new project called "Aulas tecnologicas". It consists of ten classrooms (each one with several simulators) spread throughout Spain. The manufacturer of these new simulators is Lander. The simulators do not have motion systems. About 780 km of track are represented in the simulation. All of these simulators will be available in 2008 for freight and passenger trains (CIVIA and 252). These simulators run in real time on one computer but need to communicate with a central server through intranet. The simulator includes a partial cab and a small driver desk which is close to the original using the touch screens. The simulator has an assessment database. It also has 160 km of realistic tracks and enables the use of 620 km of generic tracks (regional lines, mountains, high speed and high speed with RTMS/LZB).

The training module for abnormal and emergency situations is called a “refresher course” – it is designed to remind (and teach) drivers about rules and regulations and how to solve incidents. It consists of eight hours training in the classroom and eight hours in the simulator. Assessment is not intended.

Additional comments

RENFE is a main rail operator in Spain. The number of regular train drivers is approximately 5 000. RENFE has 92 train drivers in training. The general driving course to obtain a driving license consists of classroom training (530 hours), practice in depots (100 hours), practices in simulators (40 hours) and practice in real cab (480 hours). There are also specific courses for rolling stock and route knowledge.

6.11 S-Bahn Berlin Bahn Berlin

The S-Bahn Berlin is a modern railway carrying 1.4 Million passengers per day. They have 16 lines with a track net of 331 kilometres and 1 000 trains of type BR 481 to manage the volume of traffic. In S-Bahn Berlin, there are four CBT modules from the same manufacturer (IAS – Soft for Train) with different type of access. These modules are made for passenger trains class BR481/BR480 and BR485. The date of delivery is 1997. In this company there is one simulator named “Fahr Simulator BR 481” delivered by KMW. The urban railway driver training simulator to train cab operators of the BR481 series (manufacturer: AdTranz) of S-Bahn Berlin GmbH is installed in the locations of S-Bahn Berlin GmbH, Berlin-Schöneweide and handed over in July, 1998.

Main reasons for purchasing the simulation systems

The main reasons for purchasing the simulators were to provide initial and advanced training of the train drivers

independently of public traffic, low costs, possibility of group training and training of irregular conditions and emergency situations. The application/use of the simulator changed over the years. Trainers recognised new application areas for the German Federal Police, psychologists of the railway undertaking – training for accidents and publicity.

Main application

The simulator represents a real time simulator and can be used for simultaneous and cooperative training with other roles. It consists of a full cab replica with original controls. It also has a six degrees of freedom motion system. There are three realistic tracks 120 kilometres long in the simulator. The simulator is in charge of advanced training for four hours per trainee and per year and a competence check for 45 minutes per trainee within a period of five years. One example of a training module is a module for abnormal/irregular conditions.

The content of this module consists of running on sight due to the problems with signalling devices. It consists of two hours of theory and three hours of practice in a group of two trainees. This module is trained in the simulator and at the end there is an assessment protocol.

Additional comments

The S-Bahn Berlin has been moving people every day in Berlin for over seventy five years now. S-Bahn Berlin employs 960 train drivers and there are no train drivers in preparation yet.

Figure 61: Photo from S-Bahn Berlin simulator site

(Source: KMW)



6.12 Societe Nationale des Chemins de fer Belges

The Societe Nationale des Chemins de fer Belges (SNCB) is the former state rail undertaking of Belgium. In 2007, SNCB employs about 3900 regular train drivers. 290 train drivers are in preparation. The network that is operated by this company has an overall track length of about 3500 kilometres.

Main reasons for purchasing the simulation systems

In 1995, SNCB purchased two full mission simulators with motion systems. The systems were delivered by Corys T.E.S.S. The main reason for this purchase was to support the training of irregularities and emergency situations as part of the advanced training, i.e. how to react/operate under stressful conditions. This system, based on the engine type T27, is used for passenger

and freight trains. In 1999, SNCB started a specification process for the development of a more cost-effective simulation solution in order to get a larger number of simulators. The initial idea was to substitute parts of the instructed classroom training for completely self-instructed training on CBT, but this idea was rejected as not achievable. Instead, SNCB has realised a net of ten training centres, equipped with 30 cost-effective combinations of driving simulators and CBT.

Apart from the visual system (by Oktal), all other parts are built and realised by SNCB experts. These simulators are based on the engine type MS096, which is used for passenger trains only. Nevertheless, for the purpose of training all simulators are used for both passenger and freight train drivers. An additional reason for putting these 30 simulators into practice was an upcoming wave of retirement as a result of a highly unequal distribution of driver age. As a consequence, SNCB searched for a way to educate about 250 new train drivers every year.

In 2005, the simulator manufacturer Oktal and SNCB completed an upgrade to guarantee the compatibility of the T27 system and the SIMPACT systems.

Main application

The two full scale simulators are situated in two operational centres; the 30 reduced scale simulators in another ten centres (three per centre). One further reduced scale simulator is only used for training development and is therefore located at the development centre in Brussels. At this centre all exercises and training scenarios are developed and tested. After completion the exercises are distributed to the twelve training centres via an internal network. Every driver gets 20 hours of initial training in the SIMPACT simulator, another four hours in the T27. SIMPACT is also used for examination at the end of different phases of the initial training (i.e. Phase 2, 3 and 4). Every candidate spends about one hour per examination, which adds up to three hours

in total. Every driver gets two hours of advanced training per year in the SIMPACT simulator, and one hour every three years on the T27.

Additional comments

In the near future SNCB plans to start cross-border operations training in the SIMPACT simulators. Oktal delivers the foreign infrastructure. There are concrete plans to increase the overall simulator training by increasing the number of SIMPACT simulators. It is intended to equip these new simulators with some extra features to improve the field of application.

Figure 62: Photos from SNCB simulator site

(Source: SNCB)



6.13 Societe Nationale des Chemins de fer Francais



The company has five CBT modules and 96 simulators. For the purpose of the benchmarking process one of the 96 simulators, called PALAS, was chosen and described. This simulator was delivered in 2006-2007 by CORYS T.E.S.S. for the high speed lines (TGV trains) LN1 (Paris–Lyon), LN2 (Paris-Tours), and LN6 (Paris/Charles de Gaulle/Marne la Vallée – Strasbourg/Bale/Metz/Nancy).

Main reasons for purchasing the simulation systems

The main reason for purchasing the simulator was for training the drivers for the Eastern High Speed Train line. The training programme has been revised due to the purchase of simulators to decrease the global training

time (from 27 to 23 days) and increase the practical training time (time devoted to training) for each student (from four to 40 hours). The main usage of the simulator is nowadays the initial training with 40 hours per trainee. It is used for advanced training (three hours per trainee per year) and competence check (one hour per trainee) during the initial training. Evaluation of the simulator training takes the format of an unstructured interview or questionnaire.

Main application

The simulator represents real time simulations asking questions that must be answered by the trainee. It works on more than one computer in a local network. The simulation station includes two full cab replicas and twelve small driver desks. There are existing original controls, touch screens, mouse, etc. The full cabs have a 3-DOF motion system. There are three realistic modelled tracks of about 1 000 kilometres.

Here is an example of a training module for abnormal conditions and emergency situations: It is a part of the initial training consisting of 15 hours of theory and 15 hours of practice. The number of present trainees is 6. After training there is a performance check and an oral examination. Part of a general training to high-speed driving: normal situations (30 hours), abnormal and emergency situations (30 hours). This training is performed in a training centre; additional time is spent with drivers in a real cab after the described training.

Additional comments

SNCF is a French public railway transport company for passengers and freight. It employs 15 000 regular train drivers and there are 900 drivers in preparation. Training objectives are fully defined by SNCF, references are written on a company level and instructors define the practical implementation of these references in the training modules. SNCF plans to extend the high-speed

train simulators to other high speed lines in France. The replacement of existing high speed training simulator ("TGV reseau"-type) from 1993 is also planned.

Figure 63: Photos from SNCF simulator site



6.14 Southern railway



Southern owns five simulators in two training centres. Four simulators are located in Selhurst and another in Worthing. There are plans to move one of the simulators currently in Selhurst to Worthing in the near future. The simulators were delivered in 2003 and had an upgrade in 2004. The content of the upgrade was focused on increasing the possible routes simulated (used in Southern's operation). The training system for train drivers also includes training by CBT modules, although the modules are not owned by Southern. The modules are primarily used for the qualification of new drivers.

Main reasons for purchasing the simulators

When the simulators were developed, they were expected to be used for initial training for new drivers and introducing new models of rolling stock. However,

now there is more use of the simulators for experienced drivers, which was not envisaged at the time they were purchased. In the future, Southern would like a more interactive simulator, where the driver could interact with CBT (for example) as opposed to an instructor, to run a scenario. The trainee would be allowed to progress through a scenario, depending on their responses to the scenario, which would be monitored by the "intelligent" simulator. This would save the overhead cost of instructors, plus increase simulator accessibility.

Main application

Simulators are used for all modes of training. The initial training represents the greatest proportion of use, averaging about ten hours per trainee. After that, follow advanced training and competence check (two hours per trainee per year and one hour per trainee per year respectively). Training for experienced drivers is focused on decision making during incidents.

The simulator is combined in training with other possible training methodologies (includes CBT, real cab, classroom etc.) to present a “blended learning” approach. One of the most important areas of simulator use is the focus on human factors and low adhesion circumstances. Human Factors training involves train drivers being faced with complex scenarios, a number of scenarios simultaneously or driver distraction. For low adhesion training, a specific training day has been developed using both simulators and classroom-based theoretical input (for a new driver, with under one year of service). This will cover driving techniques (acceleration / braking), specific areas of low adhesion and Southern’s Professional Driving Policy.

Additional comments

There is also a simulator-based programme for “three year drivers” (i.e. drivers who have passed the three year probationary period), which emphasises all the conditions

of good practice driving, so these drivers do not become complacent. As described above, Southern is planning to have a more interactive simulator, where the driver could interact with CBT (for example) as opposed to an instructor to run a scenario. Other plans include a review of simulator location or possibly buying an additional simulator, which will be based on a business case and the need to re-design the existing train driver course.

6.15 South West Trains



SWT (South West Trains Limited) is one of many transport companies in Great Britain which is specifically focused on passenger transport. In December 2002 SWT purchased four simulators manufactured by Krauss-Maffei Wegmann (KMW). The simulators are used for simulation of generic line for passenger trains, Class 450 Desiro units. These four simulators have been subject to upgrade on several occasions. Once being for graphics and the others being for activation of wheel slip/wheel slide arrangements, to align with other SWT traction.

Main reasons for purchasing the simulators

The introduction of the Desiro, Class 450, required stock conversion training for 1 200 drivers – the simulators were purchased with this in mind, and were funded by the UK Strategic Rail Authority (no longer in existence

as a UK industry body). This funding also included the full training facilities as well as the simulators. It was also recognised that the simulator could be used post conversion programme for “general driver” training, post incident training and assessment.

Main application

At present, the training on the simulator includes only basic driver training, driver manager assessment and post incident training as necessary, and allocates about 21 hours per trainee on a basic driver course. In the near future, January 2008, it is planned to use the simulators as part of the train driver competence assessment process for all SWT drivers. Each driver will come to the training centre for a 4-hour session every four years. It is possible to use a simulator for all types of education within communication with the driver (this type of simulator can not ask questions and accept the answers). Simulators are also used for competence check

for managers (not drivers), approximately two hours per manager. Simulators are used in basic training with a combination of classroom and simulation for events such as: driving under normal conditions, technical knowledge (fault situation is training), dealing with irregular situations, e.g. single line working, emergency call procedure, including emergency communications. Because the simulators are used for training purposes only, there are no detailed assessment sheets and criteria for any scenario as yet.

The SWT simulator has one disadvantage: It is not easy to create a new section of track for a new scenario (in part this could be an issue of maintaining competence). A template structure for initial training simulator sessions does not exist – with the exception of one for low adhesion training. In general, a structured set of simulator scenarios is not in place.

Additional comments

SWT has about 1200 drivers but has no new drivers currently in basic training at the training centre. With four simulators SWT would like to reach a level of more efficient training. In the future SWT hope to improve the use of the simulators in training and assessment. It is planned that the simulator will be used for all driver competence checks from January 2008. Each driver will come to the training centre for a 4-hour stay every four years.

Figure 64: Photos from SWT simulator systems

(Source: KMW)



6.16 SSB

Stuttgarter Straßenbahnen AG

SSB operates the light railway system in Stuttgart, Germany. SSB also operates the tram and bus systems in Stuttgart. The system covers much of Stuttgart and also reaches the surrounding area. The SSB runs 130 kilometres of light railway lines. In the city centre as well as in other densely built-up districts of the city, the light railway system runs underground. Outside the densely built up areas, the system runs on the surface, often along roads with level crossings, though on a separate right-of-way. SSB employs 650 regular train drivers (and another 250 drivers for maintenance and fire fighting) and has approx. 40 train drivers in preparation. For the training of the drivers, SSB uses six CBT modules (for the training contents: basic knowledge about rail system, signalling, stress prevention, ATP, rolling stock,

fare structure and management) and one full mission simulator with motion system and a full train replica (cab and first coach) delivered by Krauss-Maffei Wegmann. The simulator which represents two real lines (35 kilometres) was purchased in 1997 with a last modification in 2003 (PC-based visual system, new projectors, etc.).

Main reasons for purchasing the simulators

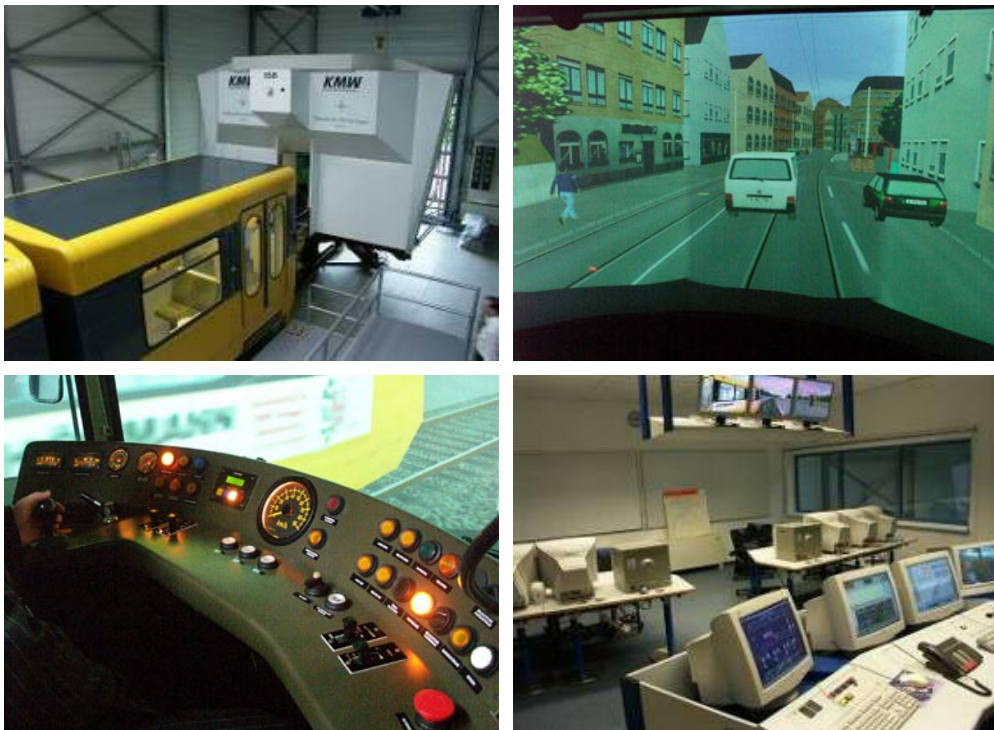
The main reason for purchasing the simulator was the training of train drivers in fault finding and related corrective measures as this topic can not be simulated in the real environment. Another reason was the aim to make the education more structured and systematic. As a consequence, the simulator training made the overall training of drivers more cost efficient.

Main application

The simulator is used for the training of, for example, irregularities during train operation, operation of train control systems, rolling stock training (therefore electronic flow charts of some technical engine subsystems can be simulated), decreased adhesive circumstances, emergency situations, customer oriented behaviour and human factor training. In the context of human factor training the simulator is used for the reintegration of employees with PTSD (Post traumatic stress disorder). Furthermore, the simulator is also used for staff recruitment in the course of an assessment centre. The overall amount of initial training is 50 days per trainee. During initial training the simulator is used for ten hours per trainee. Furthermore, it is used for advanced training (0.5 hours per trainee/year). In summary, the simulator is used 50% for initial training, 40-45% for advanced training and 5-10% for staff recruitment. The results of the knowledge tests in CBT are stored in

an information system which enables the chief operating manager to supervise the learning history of every employee. As far as the results of simulator drives are concerned only information about the fact that the trainee has made a drive is stored in the system.

Figure 65: Photos from SSB simulator site



6.17 Transports Metropolitans de Barcelona



TMB is a company focused on city transport. At present, TMB uses a simulator (running on more than 20 PCs), which was built in 2007, is known as EVA (Simulator virtual de Averías) and was made by CITEF-SIC. It is based on one simulated line with ten stations and also includes ten kilometres of rails. It is used for two types of locomotives.

Main reasons for purchasing the simulators

The main reason for purchasing the simulator is that TMB needs to train drivers in failure finding and in advanced training, focused on situations which cannot be trained in routine service.

Main application

TMB uses simulators after the initial training (28 hours of theory and 60 hours of practice) when drivers have to attend a specific course called "Incidence handling". This course comprises eight hours of training in the depot and another eight hours in the simulator and is focused on emergency situations and driving under abnormal and irregular conditions. The simulator is also used for experienced drivers who have to pass four hours of a refresher course on the simulator. This course also includes four hours in depot and it is focused on revision of specific train technical systems. Route knowledge is trained by using video screener and practices, not simulators.

Additional comments

TMB has future plans to widen the simulation and to use it for more engine types. Furthermore, it should be able to create new failures and events without the need of the company that has delivered the simulator.

6.18 Trenitalia

In 2002, Trenitalia purchased four full mission simulators. The systems were delivered by EADS. Every one of these four simulators replicates a single engine type. Two simulators are located at a training centre in Milano, the other two in Florence. Trenitalia has specified the simulators as realistic as possible including full cab replica with original controls, movement system and modelling of nearly all subsystems.

Main reasons for purchasing the simulation systems

The first reason is specific to Italy: In Italy most trains run with two drivers in the cabin. For reasons of efficiency, it is planned to reduce the need for the second driver. As a consequence, the effort of a regular monitoring of the drivers' competence by means of an accompanied run will increase as the ratio supervisor/driver decreases from 1/2 to 1/1. Here, simulation could be

an appropriate solution to partly substitute for monitoring in the real cab. Secondly, it can be mentioned that driving a simulator is a suitable method to achieve a computer-based objective assessment system in accordance with the regulation process of the European driver licence. Thirdly, a new ATP/ATC system (SCMT/ETCS) is going to be implemented in the near future. The training on this system (especially in the case of a breakdown) will widen the range of the simulator application.

Main application

At Trenitalia, the monitoring schedule of the drivers' competence consists for the most part of mandatory accompanied drives in the real cab. Three annual drives are intended for the drivers of the freight and regional division, four drives for the long-haul drivers. One of these drives can be substituted by a drive on the simulator. This competence monitoring is based on the CER competence model. In case of a lack of competence, the

specific gaps are documented in a personnel book (a kind of personnel dossier) by the supervisor/instructor. This leads to a qualification activity and additional oral revision to see if the competence gap could be closed. Next to these three methods (real cabin/simulator/oral check-up), Trenitalia also analyses the incident data of the real cab records. The simulator sessions are mostly realised with five trainees whereas every trainee drives once and the other four trainees observe and finally discuss the performance of their colleague. During a simulation drive the ratio of instructor and performing trainee is always one-to-one.

Additional comments

Trenitalia has about 15 000 train drivers and four simulators. This means that regular simulator training for all train drivers is not feasible at present. In the long term, Trenitalia will make an effort to realise a simulator fleet of about 15 systems in order to use this

computer-based technology for a regular training/monitoring for all train drivers. Trade unions do not allow a detailed performance check by using objective assessment data. For that reason Trenitalia wants to involve trade unions into the simulator processes and training development in order to give them a better understanding of the advantages of using a simulator.

Figure 66: Photo from Trenitalia simulator site

(Source: Trenitalia)



6.19 Verkehrs-Aktiengesellschaft Nürnberg



The Nuremberg U-Bahn is Germany's newest metro and is operated by VAG Nuremberg. The route network consists of approx. 40 kilometres and 40 stations. VAG Nuremberg employs 150 metro drivers (and another 160 tram drivers). The two existing lines U1 and U2 will be completed in the future by the new U3. This line will be Germany's first fully automated computer-driven metro line. Since U3 will travel on part of U2, both computer-driven and human-driven trains will run on the same tracks over this shared line. VAG runs two simulators for the training of their train drivers. Both systems can be run with three interchangeable driver desks and were delivered in 2004 by Corys T.E.S.S. The last update of the simulators was in 2007

(new line U3, new engine type). The simulators are partial cab simulators without a motion system and with a replica of the controls close to the original. All three lines with an overall length of 40 km are simulated. As signalling/control systems ATP is simulated as well as ATO. VAG uses no CBT/WBT modules for the training of train drivers.

Main reasons for purchasing the simulators

The main objective for using the simulator as a training tool is the training of abnormal and irregular operational situations. This is the case because the training of the correct handling of these situations is very difficult or even partly impossible in real traffic. Furthermore, using simulation as a training method has economic benefits: fewer instructors are needed, lesser traffic load on the lines as a consequence of fewer training drives on the real track, and more cost effective training. Another advantage is the more comprehensive

training of all competence aspects that are relevant to the driver (e.g. communication) and an enhanced training efficiency (e.g. due to replay functionality).

Main application

The simulator is used for initial training (160 hours per trainee, i.e. 50% of the whole initial training) and for advanced training (four hours per trainee/year, i.e. 25% of the overall advanced training). Furthermore, the simulator is used for the recruitment of train drivers (as a part of an assessment centre). During the recruitment the simulator is used for the testing of basic communication skills and safety orientation.

The simulator is mainly used for the training of driving under normal conditions, irregularities during train operation, operation of train control systems, emergency situations, and customer oriented behaviour (e.g. communication and information). Concerning the training of the correct handling of abnormal and emergency

situations approximately 40 different training events can be realised by the simulator (e.g. running at sight, wrong direction, and person on the track and handling of defective train). The training is done in a group of 3 trainees and lasts 30-40 minutes.

Additional comments

Due to the new automated Metro System, in the near future (2008) the train driver's job profile will alter. Former train drivers will have to give passenger information in the metro stations and trains and to perform routine activities such as checking station installations. In the event of operational or technical problems, the train drivers have to be able to operate the train manually. For that reason they will undergo a weekly 2-hour-training in the simulator. At the beginning every train driver who works within the automated system will undergo 17 hours of simulator training. That is why new training objectives will be trained, i.e. how to behave if an automatic train breaks

down and a train driver has to reach and enter that train full of angry/upset passengers. There is no energy saving driving training because it is not that necessary as the whole infrastructure is equipped and realised for that purpose (elevation profile of the tracks/signals, where to turn off the engine in order to let the train just roll).

Figure 67: Photos from VAG simulator site



7. Summary and discussion



One aim of the European rail research project 2TRAIN is to give best-practice guidelines for an efficient, safety enhancing, and cost-effective use of modern technologies for the training of train drivers as well as for the ongoing competence and performance assessment. In order to reach this aim the starting point of 2TRAIN was a benchmarking of (1) training tools and technologies as well as (2) training contents and models already in use in different European countries.

The report at hand tries to provide a comprehensive overview of the benchmarking results by comparing the existing training concepts and gaining some understanding of the training background in the individual interviewed companies (e.g. training organisation, regulations concerning the use of computer-based training technology). The benchmarking process was done in a two-step approach. In a first step a screening questionnaire was sent to 75 companies from more than 20 European countries. A smaller research sample of 18

companies was then selected on the basis of the results of this first survey. The selection was based on different criteria, e.g. the size, type and location of the organisation and with respect to the experience in the area of simulator training. Among the 18 companies are those which do not yet possess simulation systems but are seriously thinking of purchasing one in the short-term future (CD), companies which are in the process of the implementation (MAV and IE) and companies which have many years of experience in operating at least one simulator. CBT/WBT modules are used in the majority of the interviewed companies except for SWT, TMB, SNCF, VAG and Trenitalia.

The research sample is a suitable representation of all European railway companies as it represents more than 600 000 employees of which are more than 77 000 train drivers from ten countries within the European Union plus Norway. Part of the research was also to include companies dealing with urban transport, i.e. metro or light

rail operators. The second step of the benchmarking process was composed of a structured interview held by the project partners with the selected railway companies. Therefore, a detailed structured questionnaire was sent to 18 selected companies in advance. This was followed by a personal meeting with the representatives of these companies with the objective of collecting as many information as possible and to minimise possible misunderstandings of the questions. At the same time there was an opportunity for a personal visit at the simulator training centres. About 40% of all simulator sessions are allocated for the initial training. Therefore, initial training is the main topic trained on simulators. Besides that, simulator training is an instrument for advanced training (~30%) and competence check (~24%). An average number of hours spent on simulators by a train driver within the scope of initial training is approx. 30 hours. There are companies which use simulators for initial training considerably above average,

i.e. for example 35, 40, 60 or even 160 hours per trainee. In terms of advanced training, simulators are mainly used for the training of emergency situations, driving under normal conditions, and the training of human factor issues. In all companies, classrooms and even the real cab of the train driver still play an important role for the training of situations which cannot be substituted by a simulator, e.g. the training of route knowledge. The usage of simulator training in comparison to other training methods like classroom or real cab in concrete phases and for specific topics of training is very diverse. As a training method for initial training, simulators are only used in 7% of the overall training amount. Concerning advanced training the companies cover in average 25% of the complete training with simulation and 26% of all competence checks are realised by means of a simulator. As a consequence of these different training concepts, operators have different technical requirements; for some companies a real cab replica simulator is

fundamental, whereas others prefer lower-scaled systems like partial cab replicas or even software interfaces or – quite often – a combination of different systems. The presence or absence of a motion system is also a consequence of the different training procedures. Some companies stated that a realistic movement system is essential to reach a high immersion level of experienced train drivers. Other companies argue that the higher level of reality is not worth the higher costs of these systems. As far as the organisation of training is concerned, only very small differences among the companies appeared. The framework of training is generally defined by both internal guidelines and legal regulations which specify the range and content of the training. All in all, the analysis highlights the important role of simulation for the training and assessment of train drivers. Nevertheless, the interviewed companies stated some shortcomings that hinder an optimal use of the existing training technology. The major point of criticism is the

missing possibility to create new exercises and scenarios without the support of the manufacturer. The weak assessment capabilities of the simulators and in particular the quality of the simulator reports is another important drawback of the existing technology. In order to achieve an optimal benefit from modern training tools it is recommended that the simulator training should be embedded into the overall competence management of the company. In addition, the simulator exercises should be tailored to the intended learning objectives. Furthermore, it is important that the train drivers become familiar with the new technology by using the training tools regularly in the course of initial training, advanced training, and competence check. Standardised scenarios and procedures for all training centres of a company lead to a transparent training and assessment. The usage of simulator data supports an objective and detailed assessment of the train drivers' performance. Simulator training is an effective method

within a blended learning environment that has the major objective to guarantee highly qualified railway personnel that is able to handle all kinds of operational situations in a safe and appropriate way.

2TRAIN | Training of Train Drivers in safety-relevant Issues with validated and integrated computer-based Technology

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