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

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

2TRAIN

SIXTH FRAMEWORK PROGRAMME

The whole consortium would like to kindly invite readers and users of this report to give feedback and to make contact with the 2TRAIN consortium (info@2train.eu) in order to use the consortium's resources for future efforts in the area of training and assessment of railway staff.

Imprint:

Editors: Marcus Schmitz (IZVW), Christian Maag (IZVW)
Authors: Dusan Pouzar (CD Cargo), Jakub Pechoucek (CD Cargo), Hana Vagnerova (Ceske Drahy), Ivo Stepanek (CD Cargo), Marcus Schmitz (IZVW), Christian Maag (IZVW), Jose Manuel Mera (UPM), Alejandro Garceran (UPM), Luis Miguel Gutierrez (UPM), Stefan Endres (DB), Laurent Brue (Corys), Christian Albaret (Corys), Michael Hintenender (KMW), Eveline Ruhland (KMW), Andrew Russell (RTI), Michele Spanaki (RTI), Richard Holzer (UP), Yves Samyn (SNCF), Ales Bartheldi (CD), Tatiana Molkova (IJP)
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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 within the report. These definitions do not intend to be universally valid:

- Initial training: Training of "novice" train drivers in preparation for passing the exam (other: education, apprenticeship)
- Advanced training: Training for examined (or "expert") 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)
- 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 training schedule specification (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
- Training technology: Computer-based training methods e.g. simulation, CBT/WBT

In combination with Simulator or Training:

- Session: A whole training unit (may include briefing, a 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 one 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

Introduction

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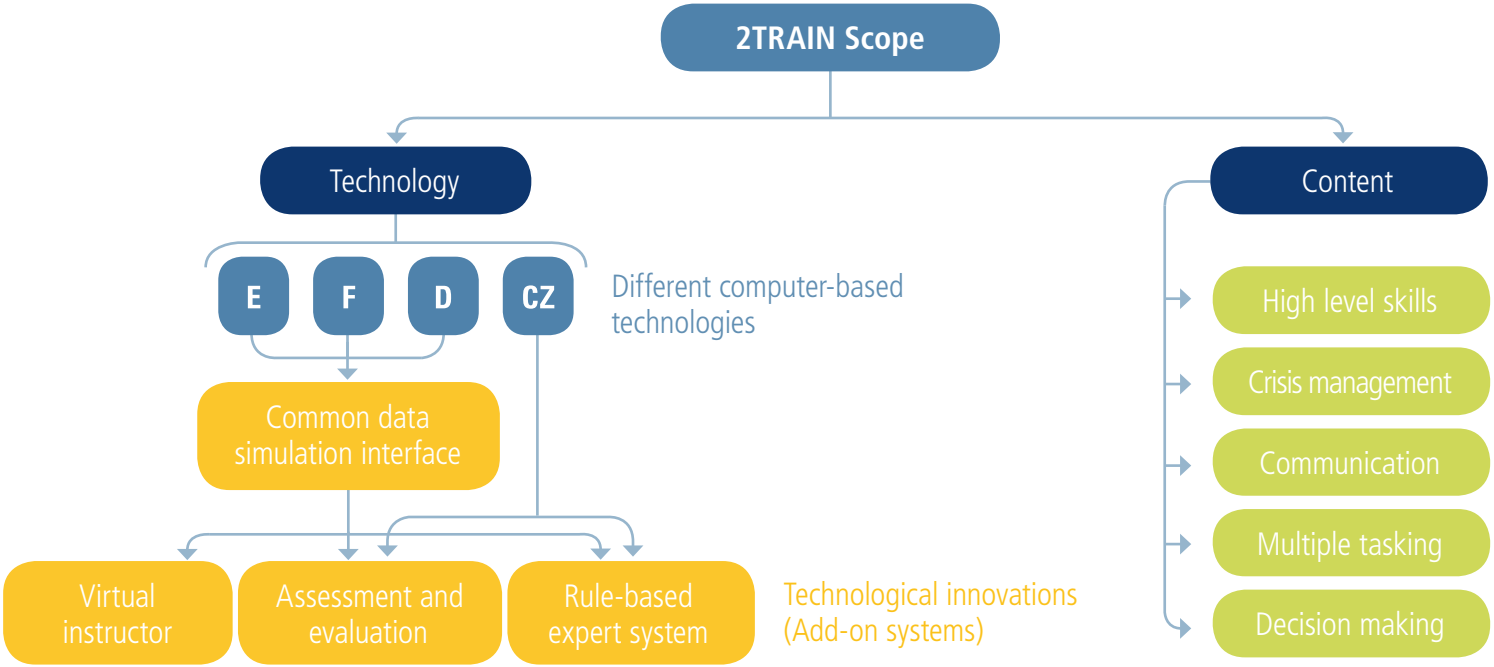
1.1 What is this report about?

This final report gives an overview of the complete 2TRAIN project work undertaken within 39 months. Owing to the fact that most project deliverables are available to the public on the 2TRAIN website, this report seeks to summarise results and give recommendations that could be helpful for railway companies as well as for other institutions that provide training of railway staff. After a brief introduction of the project's objectives and the consortium in this chapter, the report summarises the three main phases of work: (1) the research phase, (2) the development phase and (3) the evaluation phase. All conclusions, guidelines and recommendations that derive from the project's work and from the extensive exchange with stakeholders from all over Europe are outlined at the end of this report. The final report is therefore not only a summary of the project. The recommendations should also guide future scientific research and serve as background for future development of modern training technology in the European railway market.

1.2 The 2TRAIN project

The European railway sector is a continually growing economic area that is characterised by an increasing internationalisation and exchange between countries. In addition, recent years have brought about frequent and large developments in rail technology. Responding to these tendencies, the European Commission aims at enhancing rail safety as well as improving the harmonisation and interoperability between railway systems. This also ensures the competitiveness with other traffic systems. Because of the diversity and incoherency of different traffic systems (road, rail and maritime) the 2TRAIN project is focused on the railway sector and particularly on the optimisation, development and evaluation of computer-based training systems for train drivers in Europe.
Starting point of 2TRAIN was a benchmarking of training tools and technologies as well as training contents and models already in use in the different European countries. Based on these results, requirements for training technology, contents and models were specified in order to adjust the further project steps to users' needs and to define common training situations (simulator scenarios and CBT/WBT modules).
The development and implementation of a common data simulation interface (CDSI) overcomes existing differences in European training technologies and allows a standardised data recording, driver assessment and evaluation as well as the implementation of a virtual instructor (VI).
In addition, a rule-based expert system (ExSys) in national variants gathers the target behaviour of the train driver for different situations. The comparison of target behaviour (ExSys) and actual behaviour (simulation/CBT data) of the train driver provides the data for both a virtual instructor and an assessment database (AssDB). The whole concept of the 2TRAIN add-on tools is described in Figure 1.

Figure 1: The scope of the 2TRAIN project
(E: Spanish demonstrator; F: French demonstrator; D: German demonstrator; CZ: Czech demonstrator).



Four national pilot studies demonstrate the technical developments within the 2TRAIN project, as well as their acceptance and resulting learning effects.

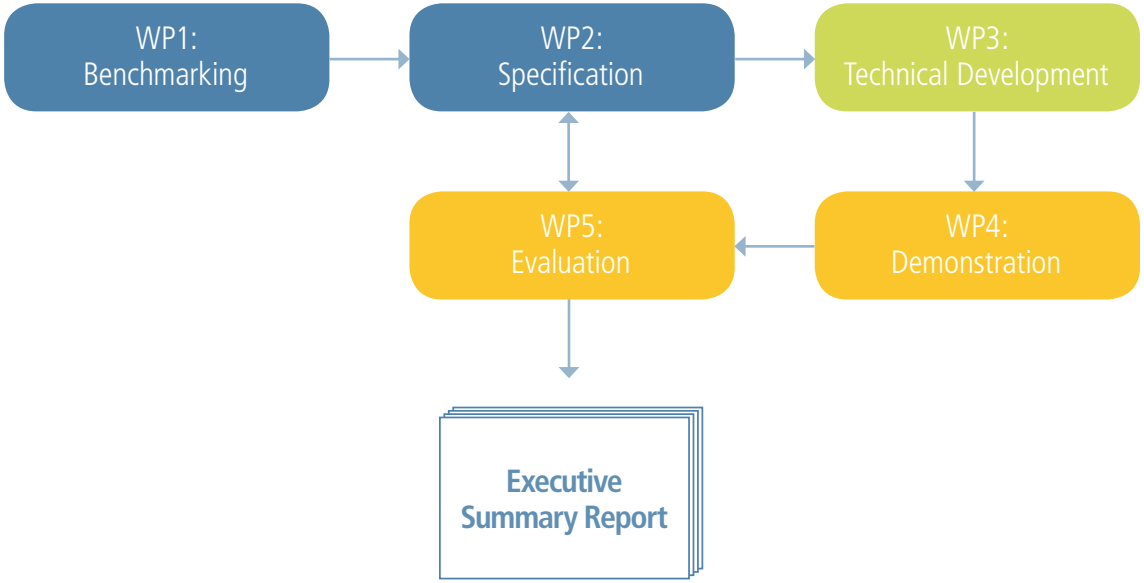
During the realisation of the project many small as well as large objectives and milestones were set. The list of the most important project objectives are explained as follows:

- To benchmark existing and emerging training tools and technologies (such as multimedia training, driving simulators, virtual and augmented reality based simulation) as well as training contents against the actual needs and priorities of railway companies and train drivers.
- To agree on a minimum set of technical specifications for the development of computer-based systems for driver training and assessment.
- To define and implement appropriate scenarios for existing train and light rail simulators with emphasis on the realistic simulation of emergency situations, as well as corresponding CBT modules.
- To develop, implement and evaluate a common data simulation interface.
- To build a rule-based expert system being able to take into account national and regional differences.
- To develop and implement a virtual instructor and an assessment database.
- To build up demonstration pilots in order to evaluate and validate the feasibility, usability and usefulness of the technologies, concepts, and scenarios developed within 2TRAIN.
- To explore the potential impact of 2TRAIN on safety and other social benefits as well as to define their cost-benefit (for developers) and cost-efficiency (for society) ratio.
- To phrase guidelines that will describe how the training, the assessment and examination of a train driver should be accomplished and how the information about the train driver's performance should be integrated into the railway companies' competence management.

- To produce detailed exploitation and business plans for the developed computer-based systems and compare them with "old style" training taking place in the real environment (with high costs caused by equipment staying out of services).
- To disseminate 2TRAIN project results to all relevant and interested parties.

The 2TRAIN project consisted of seven work packages, each with a specific output. The final report concentrates on work packages WP1 to WP5, which represent the core of the project, and leaves out management and exploitation issues. The dependencies of these five work packages are shown in Figure 2 representing the workflow of the whole 2TRAIN project.

Figure 2: Graphical presentation of work packages.



1.3 2TRAIN consortium

The project's consortium consisted of eleven participants including train operating companies, scientific institutions, and simulator manufacturers.
Coordinator: Center for Traffic Sciences, University of Wuerzburg, Germany (IZVW)
Train operating companies: Ceské Dráhy, a.s., Czech Republic (CD) /CD Cargo, a.s., Czech Republic (CDC) / Deutsche Bahn AG, DB Training, Germany (DB) / Société Nationale des Chemins de fer Français, France (SNCF)
Research Institutes: Jan Perner Transport Institute, University of Pardubice, Czech Republic (IJP) / Rail Training International Ltd., United Kingdom (RTI) / University of Passau, Germany (UP)
Simulator manufacturers: CORYS Training and Engineering Support Systems S.A., France (Corys) / Krauss-Maffei Wegmann GmbH & Co. KG, Germany (KMW) / CITEF, Universidad Politécnica de Madrid, Spain (UPM)

1.4 2TRAIN user group

The impact of the project was increased by establishing a user group of companies that were interested in the objectives of the 2TRAIN project as well as in the final results. The project team held two user forums inviting the user group and further European stakeholders for an information exchange on computer-based training and assessment procedures.
The participants of the user forums provided interesting feedback and useful recommendations that helped to increase the quality and impact of the 2TRAIN results.
In the first user forum of the project, the idea of the project was introduced to the participants. Some of the participants presented their educational and training systems, i.e. SNCB, NSB, and Metro de Madrid. Furthermore, the main results from the ongoing 2TRAIN benchmarking process were published.

The second user forum was held in Hamburg and was mainly focused on the comprehensive presentation of the 2TRAIN project results. The add-on tools were presented to the whole audience. The demonstration included a SNCF simulator, a DB simulator and the Czech WBT.
During the presentations all participants were engaged in the discussion about the developed products, showing that many users were satisfied with the 2TRAIN results. Figure 3 illustrates the companies that are members of the 2TRAIN user group.

Figure 3: Members of the 2TRAIN user group.

2. The 2TRAIN Research phase

The 2TRAIN Research phase

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2.1 Benchmarking process

The term benchmarking is frequently used in management and describes the evaluation of the processes of organisations in relation to best practice. A benchmarking process had been chosen as part of the 2TRAIN project, because it was necessary to assess the current situation in the area of training of train drivers and subsequently to compare it with the needs of all railway stakeholders involved. Furthermore, the benchmarking phase provides a comparison of the existing training and technology standards and the current situation in order to highlight the gaps that should be improved by the subsequent steps taken by 2TRAIN – i.e. the research activities connected with the development of simulator add-on tools.
This benchmarking phase provided the key data to feed the whole 2TRAIN research and development efforts. The objective was to review and summarise existing standards in the area of training technology, training contents and training models and to compare these standards with the current procedures of train driver training in the different railway companies in the EU.
A brief paper-based screening questionnaire was sent to more than 75 railway undertakings from more than 20 countries across Europe to provide a preliminary summary of the use of simulation and CBT/WBT modules. As a result of this analysis, a sample of 18 railway companies was selected for a more detailed face-to-face interview based on key question forms (Figure 4).

Figure 4: Benchmarked companies
The results of the face-to-face interviews are provided in the 2TRAIN Benchmarking report on computer-based railway training in Europe (available at www.2TRAIN.eu).

2.2 Specification process

The specification process serves as a link between the research and the development phase of 2TRAIN. During the specification, the following three tasks were carried out:

Specification of training technology

The specification took into account the results of the pan-European benchmarking process. It specified the add-on modules that enable the efficient use of existing simulators and CBT/WBT modules and the functional connections with the assessment and evaluation systems by any European rail training provider. The specification placed the emphasis mainly on the development of four add-on tools:

- Common data simulator interface (CDSI)
- Rule-based expert system (ExSys)
- Virtual instructor (VI)
- Assessment database (AssDB)

In addition, CBT/WBT modules should be developed in Czech and German. The German solution should be connected with the German simulator (at least content-wise), whereas the Czech solution should provide computer-based training without any connection to a simulator system.

Specification of training content

The specification of the training content was to identify common training content across the four national pilot sites. Given the different types of simulators in the 2TRAIN project, it was necessary to find contents that could be trained in all types.
The common training situations were implemented in the driving simulators and CBT modules, and provided a basis for the demonstration and evaluation of the functionality of the simulator pilots and the add-on tools. This means that subsequently these defined training situations were realised in simulator scenarios and CBT modules. Some of these situations were common for the most European rail systems, but at least two or three situations took into account specific differences (e.g. situations mainly occurring in light rail traffic).

Specification of training models

The term training models comprises all questions about how the concrete training proceeds, i.e. assessment procedures, briefing or offhand, individual or group training, repetition schedules. The trainees' characteristics are also taken into account in terms of educational requirements, professional qualification, and operational area.
The specification of the training model focused on the field of learning theory and instructional design, including training needs analysis, training design, training delivery, evaluation methodology, cognitive style analysis, instructional design models, and adult learning concepts. As a result, the 2TRAIN project took into account the ability of drivers (entry level competence) and the training environment. Furthermore, the project team decided to introduce some tools into the research phase to measure train drivers' cognitive style.

3. The 2TRAIN Development phase

The 2TRAIN Development phase

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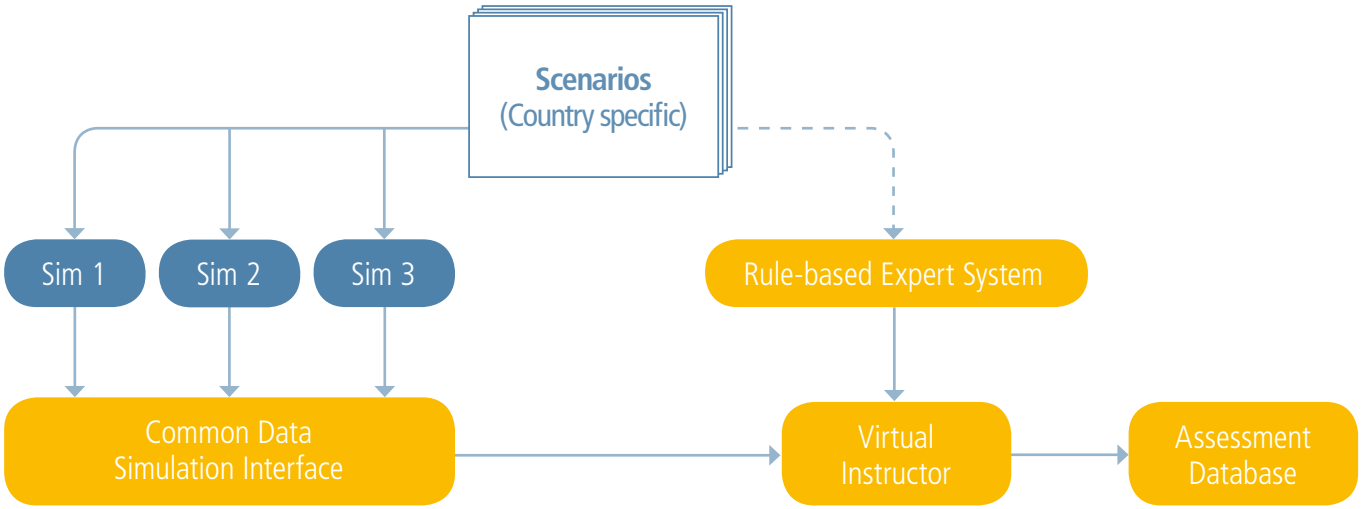
The development phase was covered by work package WP3. This chapter includes mainly general information about the functionalities of the technical developments due to intellectual property rights. For the simulators, the add-on modules have been developed to perform the following tasks:

- The common data simulation interface (CDSI) enables the different modules to exchange data, defines the transmission mode for each variable (continuous or event), transmits data between machines with different data format, records the variables transmitted during a simulation run and replays them later, and finally enables the modules to exchange notifications (not defined through variables).
- The rule-based expert system (ExSys) creates and edits assessment rules, allows the instructor to perform subjective assessment as received by CDSI messages, and displays values of arbitrary selectable CDSI variables with configurable format.
- The virtual instructor (VI) parses and loads assessment rules, performs the real time assessment based on target behaviour, collects assessment data during the simulation run, delivers subjective assessments to the real instructor through CDSI messages, creates simulation plots used by the exercise report, stores all assessment data on the AssDB. Furthermore, the VI displays help messages on the screen (Help mode), and pauses the simulation and plays training multimedia files (Guidance mode).
- The assessment database (AssDB) receives assessment data from the VI and/or CBT modules and stores the data in a database, has a graphical user interface with role based access to the stored data, displays assessment data on the screen, and exports assessment data into a file, which can be used by other software. The last point is notably used to create an exercise report.

Figure 5: The interaction of add-on tools



All these modules have been designed and developed to be compliant with all the simulators used for the pilots. Figure 5 illustrates the interaction of the 2TRAIN add-on tools. Within work package WP3, not only technical tasks were developed. In order to have the system ready for training and assessment, two more elements were needed: The definition of assessment parameters, thresholds and schedules, and the preparation of the training and assessment exercises.

3.1 Common data simulator interface (CDSI)

The CDSI was developed to establish connections between the processes and computers involved in online processing and to transfer (1) variables from publisher to subscriber and (2) messages from sender to addressee.
CDSI works over an Ethernet data communication network. It is a library rather than a module. Each module or interface that needs the CDSI features links up to the library and calls its functions (application programming interface, API). CDSI is delivered as a set of source files written in C++ files. Each user of CDSI has to compile and link the sources in order to make a library, compile its C++ source while including the headers and calling the functions of the interface, and link its library or process with a dependency on the CDSI library.

3.2 Rule-based expert system (ExSys)

The main aim of the ExSys was to provide an opportunity to define the expected behaviour during a simulator exercise. By that, it allows a comparison of target behaviour to the driver's actual behaviour. The ExSys helps the instructor with the evaluation of the train driver's performance. ExSys works in two connection modes: offline and online. In the offline mode, ExSys behaves basically as a rule editor. It allows the management, creation, amendment, and configuration of the rule sets. In online mode, ExSys provides an interface for the instructor to monitor and influence the assessment process during a simulation run.

Offline tasks of the ExSys

The instructor could work with the ExSys offline system from an independent PC/note-book. Through the ExSys the instructor could work on the assessment scheme for a specific simulation scenario. He could create rules and adopt the parameters and thresholds for any given situation. For the offline tasks three important tools were developed:

- Creation and amendment of rules – The ExSys allows the creation of the rule for testing the actual behaviour. Rules are created in the offline mode, but the CDSI variables must be available.
- Configuration of rules – ExSys allows the configuration of particular rules to the given national regulations and railway systems.
- Creation of position markers – The application of a rule (e.g. supervision of the speed limit) in a given situation the speed limit increases at an exit signal. But sometimes

a rule should be applied in a situation where no reference point exists. For example, an emergency brake must be given due to an obstacle on the track. But the obstacle is not a reasonable starting point for the supervision of the brake system. In these cases, the ExSys can create position markers that should trigger the assessment at a specific point on the track.

Online tasks of the ExSys

Some general data needed by the assessment system can be supplied by the instructor at the ExSys GUI, e.g. name of instructor, name or ID of trainee, post run comment and enable/disable the assessment system. This input is optional; with some pilot simulators it may be available from the pilot and forwarded by CDSI instead.

- Subjective assessment – During a simulation run, a GUI is presented to the instructor by the ExSys module for subjective assessment. Rules can ask for subjective assessment in particular situations: The VI triggers the presentation of accordant messages on the ExSys GUI at the instructor's notebook and receives the instructor's answer from ExSys as additional assessment data.
- Instructor comments – The online instructor GUI of the ExSys module has a button to open a text field to enter the comment and then send it to the VI. This information is handled like any other event during a simulation run and can be picked up by a "comment-rule", which decides e.g. whether it is shown in the final assessment report (probably together with simulation time, train position et cetera).
- Feedback data for assessment – The online instructor GUI of the ExSys module presents feedback data from the VI module and current values of selected CDSI variables during the simulation runs.

The ExSys GUI always shows the current values for:

- the time since start of the simulation run (as calculated by the pilot simulator)
- the train position (according to CDSI concept)
- the train velocity
- the train acceleration
- CDSI values describing the current rule states, sent by VI (to be defined)
- three more CDSI values, selectable by instructor

Additionally, a list of events is shown (and stored in the log file). Each event is represented by one line with entries for: time, train position, train velocity, train acceleration, name of the CDSI variable which triggered the event, and the (new) value of the CDSI variable.

3.3 Virtual instructor (VI)

The VI phrases and evaluates in real time a set of rules given by the ExSys as XML file/files. According to these rules (based on a finite state machine) the VI executes functions (e.g.: send messages, pause simulator) and creates all assessment data which is sent to the AssDB at the end of the exercise. The main tasks of the VI are as follows:

- Start and stop assessment rules (activate or deactivate them)
- Evaluate active rules in real time
- Send help messages and multimedia files to the driver (through CDSI messages)
- VI can ask the simulator core (through CDSI messages/ variables) to stop, play and resume an exercise (e.g. in order to give additional information to the driver).
- Receive subjective assessment from instructor
- Receive comments from instructor
- Send assessment data to the AssDB once the exercise has been finished and create the necessary information for the creation of the final report

About the state of the rules

When the simulator is launched, all rules in the scenario XML file are loaded, although this does not automatically imply that VI will start the evaluation of all these rules. Rules are only evaluated when they are in an active state. All loaded rules are activated at the beginning of the exercise but the rule itself can decide when it will start to evaluate (e.g. if a specific position marker is passed).

Working modes at VI

VI has three available working modes:

- Guide: For initial training/learning
- Help: Some advice (usually when trainee has done something wrong)
- Assess: No advice, only assessment

Some learning modules are integrated to the scenarios of the simulation pilots, taken from the definition of common training situations. Using these modules, and in the case of Guide and Help modes, drivers can go through the different steps of the training path, receiving coherent information and help while performing their training exercise.

Data from/to other modules

In order to make an effective real time evaluation, the VI needs information from other modules present in the 2TRAIN project:

- Scenario rules – Before starting an exercise, the VI receives/gets a XML file (created by ExSys) where the VI finds rules used during the exercise.
- CDSI variables – Once the evaluation of rules has started, the VI has to compare the target behaviour against the trainee behaviour. The target behaviour of each aspect is loaded from the rules while the trainee behaviour is reached through CDSI API.

Data to the other modules

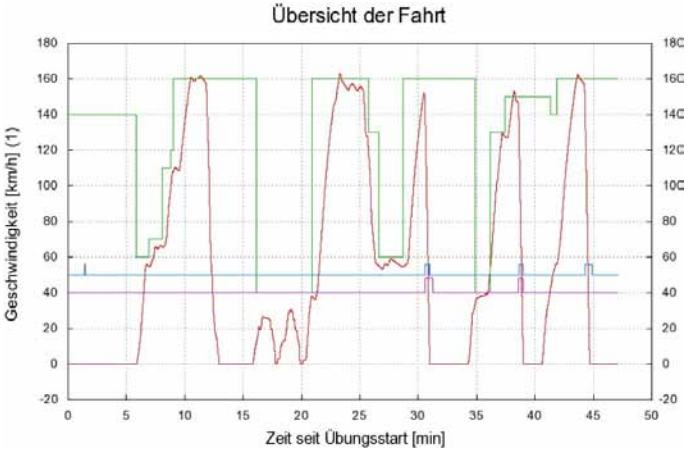
Finally during the execution of the exercise, and when the exercise has been finished, VI interchanges information with other modules as follows:

- To the online ExSys – In order to inform the online ExSys about the state of each activated rule, all loaded rules publish a variable which show the current state of the rule defined as a unique integer. This value is zero if the rule is not active.
- To the AssDB – Once the exercise has been finished, VI sends to the AssDB all assessment data (plot included) of the exercise through an ADO connection. The information sent includes all relevant performance data selected in the rules and the information given by the instructor (subjective assessment and comments).

3.4 Assessment database (AssDB)

The AssDB allows to store data from each training performance. By that, AssDB provides information about the performance of trainees during a simulation run. It is also possible to compare the results of each trainee and create summary reports of all simulation runs. The AssDB communicates with the VI and with the CBT assessment unit. The interface to these two other modules is used for storing simulation run data and assessment data in the database and to receive data from the database. For the storage of data, a SQL statement will be sent from the other modules to the AssDB. For receiving data from the AssDB, the other module (VI or CBT assessment unit) sends a SQL query to the AssDB, which indicates which data should be received. Communication between the AssDB and the two other modules is made through ADO. For the database management system, PostgreSQL is used. The exercise report summarises the exercise results. A summary of the critical errors made during the simulation run is displayed at the top of the report, in order to see the most important result: Has a safety critical mistake occurred? A graphical overview displays assessment parameters of interest. The parameters that the graph contains can be configured by the user. In Figure 6 the rectangular line represents the target speed and the curved line represents the actual speed. Whenever the curved line is above the rectangular one, the trainee has exceeded the speed limit. This overview is a supportive tool for the debriefing of the session.

Figure 6: Illustration of a graphical overview of the exercise (German version)



The main part of the exercise report is a chronological order of each relevant situation throughout the simulator run. In case of a deviation the report contains more details than the information given via the ExSys online GUI.

For example, if the speed limit was exceeded, the report displays the speed limit, the actual maximum speed driven, and the duration of the speed exceeding (see Figure 7).

Figure 7: Example of a report section (speed section/specific scenario event)

Did the driver comply with the speed limit?	No, more than 5 km/h faster
LC2 km 73.8 - Sig. P1 Nersingen (40 km/h)	Speed limit: 40.00 km/h Max. speed: 49.21 km/h (AFB) Time > speed limit: 9.34 s

Irregularity at level crossing	
The driver stops the train in front of the level crossing correctly.	Yes
Did the driver comply with the speed limit?	Yes
Driver operates the horn in front of level crossing	No, too short (< 2s) Duration: 1.5 s Speed: 0 km/h
When reaching the middle of the level crossing, the driver accelerates to normal speed.	Yes

3.5 Simulator scenarios

Each simulator scenario covered some mandatory and some optional events taking into account the different railway systems and regulations. Some significant differences can be seen by comparing the national scenarios that are illustrated in Table 1.

Table 1: Training scenario of each national pilot

No	Situation	DB	MdM*	SNCF
A1	Cab brake test	X	X	X
A2	Input of train data	X	X	X
B1	Automatic application of the brakes	X	X	X
B2	Obstacle on opposite track	X	X	X
B3	Emergency brake override	-	X	X
B4	Irregularity at level crossing	X	-	-
B5	Passing a stop signal	X	X	X
B6	Problem with the closing of a door	-	-	-
C1a	Different speed sections - normal	X	X	X
C1b	Different speed sections - restricted	X	X	X
C1c	Different speed sections - on sight	-	X	X
C2	Scheduled stop at station	-	X	X
C3	Operation of train protection system	X	X	X

* Metro de Madrid

The main reasons for the differences between the German and the French pilot scenario are as follows: Both simulators are for high-speed trains. In France, the simulator for the TGV-POS and in Germany the simulator for the ICE 1 was chosen. But the SNCF (French) scenario took place on a high-speed line, where no level crossings exist, while the DB (German) scenario took place on a conventional line with level crossings. Furthermore, the French scenario contained scheduled stops at stations, while the German scenario did not contain such stops. So the missing level crossing event in France was compensated for in Germany by the scheduled stops as part of the scenario.
The Spanish pilot took place on a light rail simulator at the training facility of Metro de Madrid. This light rail is a mixture between a tramway and an underground railway which leads to different operational procedures and technical conditions in comparison to the German and French pilots. The light rail does not have a train protection system and so the proper operation of the dead man/sleeping device was monitored as a replacement. Furthermore, the input of train data and the cab brake test are not necessary on the light rail vehicle, while on the other hand the proper operation of the passenger doors is very important on the light rail. Also level crossings do not exist on the light rail, because this system operates (outside of the tunnel sections) in an urban environment with standard street/rail intersections. In addition, the passing of a red signal is a well-known situation in a light rail system, because outside of the tunnel sections there is always an „on sight" operation.

3.6 CBT/WBT modules

Two CBT/WBT solutions have been developed for the 2TRAIN pilots: (1) a WBT programme by Ceské Dráhy as a stand-alone solution without a simulator and (2) a CBT programme by Deutsche Bahn containing situations that were also part of the simulator scenario. In both cases, the programmes were linked with a locally available version of the AssDB.

Czech WBT modules

The Czech WBT modules were focused on initial training. Therefore, the concept is based on broader explanations of the regulations. The modules are seen as a modern addition to the classroom training.

The following situations were part of the Czech WBT:

- Cab brake test
- Automatic application of the brake
- Obstacle on the opposite track
- Irregularity at level crossing
- Passing a stop signal
- Problems with closing of the door

For the development the ToolBook system was chosen. In general, the developed modules for trainees can be distributed over the internet, intranet and local area networks. For the evaluation of each trainee's training, the learning management system iTutor was used. This system also made it possible to store the data and assessment results in the AssDB.

German CBT modules

The German CBT modules were made for advanced training and were developed in parallel to the German simulator scenario as a kind of theoretical preparation. The following modules were included:

- Irregularities at level crossings
- Passing a signal at danger

The CBT modules were developed as a stand-alone solution on a local PC. It was programmed by using the Sumatra developer version 8. The structure is competence based, which means that each lesson starts with a short scenario/ situation and is then followed by a question, related to the scenario/situation. Additionally, at the beginning of the programme the student has to go through a test (pre-test) with some questions. The test is repeated at the end of the programme (post-test) in order to compare the test results.

4. The 2TRAIN Evaluation phase

The 2TRAIN Evaluation phase

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4.3 Evaluation results 45

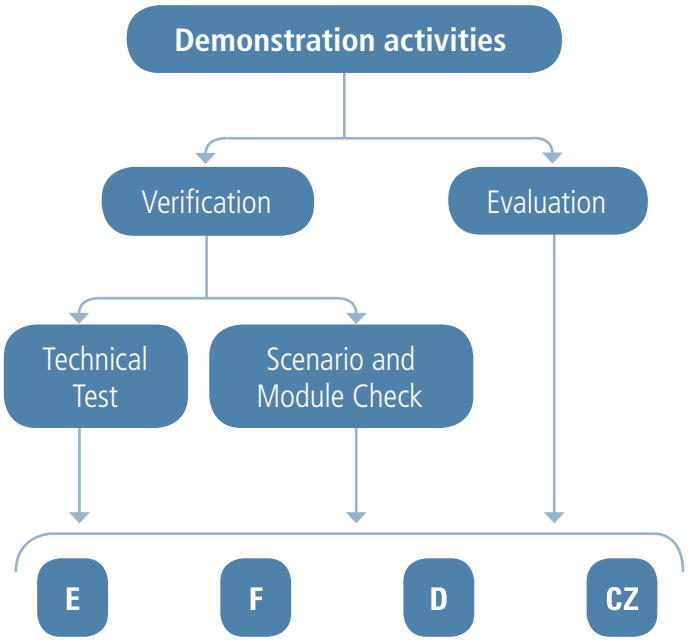
4.1 Methodological framework of the pilot studies

After the technical development of the different add-on tools, the main objective of the subsequent demonstration activities lies in the functionality and acceptance testing of the software tools and the 2TRAIN assessment concept. Four different demonstration sites were planned in order to implement different solutions and combinations. On the whole, the demonstration activities can be divided into two main categories, i.e. (1) verification tests and (2) evaluation:

- During the verification tests and checks, the tools developed in 2TRAIN were tested only in terms of functionality. Thus, these tests allow the tracking of any possible problem of the system that eventually could provide feedback to the technical developers. The verification also served as a first test of the scenarios and modules selected for the latter evaluation. The participants of the verification were recruited from the personnel of the partners.
- During the evaluation studies, trainers and train drivers evaluated the 2TRAIN assessment concept and the add-on tools. The evaluation studies focused on usability, acceptance, and learning effects.

Figure 8 gives an overview of the demonstration activities planned in 2TRAIN. In order to guarantee comparable results of the demonstration activities at different European pilot sites, it had been essential that a common methodology and common instruments were used. Therefore, every involved partner chose a national evaluation team that was responsible for evaluating the qualification modules. The partners had to analyse the data and summarise the results of the national evaluation study in a national report. All partners made use of a standardised set of questionnaires and a standardised interview guideline for the final discussion.

Figure 8: Overview of demonstration activities

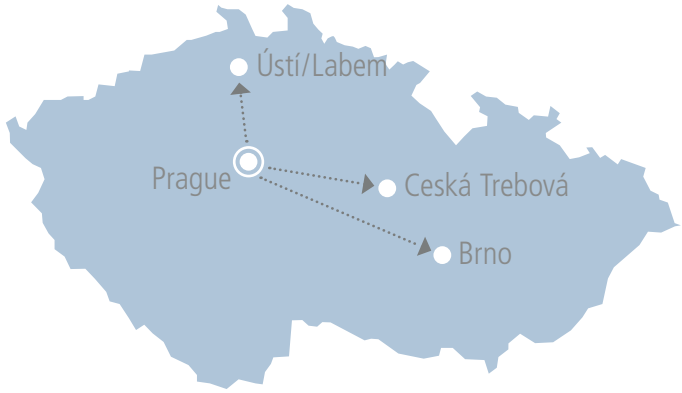


4.2 Description of sample and procedure

Czech pilot study

The Czech pilot took place in October and November 2008 at four different training centres of Ceské Dráhy (Ústí nad Labem, Prague, Ceská Trebová, Brno). The 38 train drivers were chosen from depots that are located in the area of the training centres of the Transport Educational Institute (DVI). The drivers had to pass through four WBT sessions in about six hours. The main server for the WBT modules is located in Prague.

Figure 9: Main locations for the CBT evaluation study



German pilot study

44 train drivers participated in the German pilot study at the simulation training centre in Fulda. The study was conducted in autumn 2008 on a high-speed ICE simulator with motion system. The evaluation study is carried out by inviting a small group of up to four participants per day. Within about 5.5 hours the participants had to pass three different stations. The stations were: 2TRAIN simulator exercise, CBT modules, and simulator demonstration of the VI working mode Help (& Guidance). Whereas the CBT and the simulation exercise were done individually, the demonstration of the VI working modes Help and Guidance was done by both participants together on the simulator.

Figure 10: ICE simulator

Level crossing situation with help text displayed in the visual system.

French pilot study

21 train drivers participated in the French pilot that took place in early 2009 at the simulation training centre of SNCF in Lille. The partial cab simulator without motion system was a high speed TGV-POS simulator (see Figure 11). All participating train drivers are employed as high-speed train drivers and had to go through a simulator exercise. The evaluation study was carried out by inviting each driver individually. Each session therefore included one driver and one instructor. The situations were implemented on the SNCF line between Paris-Est and Champagne-Ardennes stations, which includes normal (KVB control system) and high-speed (TVM control system) sections.

Figure 11:
TGV-POS simulator at SNCF training centre in Lille

Spanish pilot study

15 drivers participated in the Spanish pilot that was run at the simulation training centre of Metro de Madrid. The Spanish sample was the youngest sample with about two years of experience in driving suburban trains. The study was conducted in April 2009 on a light rail mini simulator and in parts on a mock-up of a Citadis TGA302 (see Figure 12.1 and 12.2).

Figure 12.1:
Small mock-up simulator during pilot scenario

The drivers went through a simulator exercise and a demonstration run of the VI working modes. The evaluation study was carried out during three sessions with two instructors and five drivers each. Although the scheduled duration for each session was two hours, the existence of one small mock-up position, with a more realistic appearance giving the drivers the opportunity to run the scenario again voluntarily, extended the total duration of the sessions in some cases beyond these two hours. As there was a mini simulator for each driver, all sessions were performed in parallel. Table 2 rises the key figures of the 2TRAIN national demonstrations.

Figure 12.2 : Mini simulator during pilot scenario

Table 2: Description of the four national samples

Country	Sample size	Simulator type	CBT/WBT	Simulator exercise	VI working mode
Czech Republic	38	None	4 modules	none	none
Germany	44	Full cab with motion	2 modules	ICE simulator	assessment, help, guidance
France	21	Partial cab without motion	none	TGV simulator	none
Spain	15	Mini simulator and partial cab	none	Light rail simulator	assessment, help, guidance

4.3 Evaluation results

The added value of any technological development must be put to the test of the feedback from end users in order to ensure that it not only complies with specifications in the light of the tests done by its designers, but also that its user-friendliness, its reliability and its efficiency allow the groups of persons it is intended for to use it. Since the main goal of the developments performed in the scope of the 2TRAIN project is to provide efficient tools for the training of train drivers, the feedback of the instructors and drivers who have used the system is studied.

Technical tests

A verification of the add-on modules has been done during the technical tests carried out by each development team on the German, French and Spanish simulators.
A total sample of nine instructors has been involved in the project, which means that the results have to be handled with care due to that relatively small sample size.
Five questions were asked related to the evaluation of the add-on tools. The agreement of the instructors with these statements is presented in Figure 13, which displays the average marks obtained on all three pilots.

The first statement about assessment database gets a very positive agreement from all instructors. At all pilots, all instructors agree or totally agree with it. The (relative) lowest mark was obtained in Germany, where all instructors answered that they agree (mark = 4). In Spain and in France, some full agreements were obtained (mark = 5).

The second and third statement about the ExSys and VI obtain the same results: the instructors generally agree with the statements, all answers being either positive or neutral. Nevertheless, answers have been quite different depending on the pilot:

- In Germany, results are excellent: almost all instructors fully agree with the statement.
- In Spain, results are good.
- In France, the results are good or neutral: the understanding of the operation and handling of the ExSys and the possibility of using it to define target behaviour of the driver is guardedly seen. The same opinion prevails on the support of the VI during the observation and assessment of the training exercise.

Figure 13: Evaluation of add-on tools

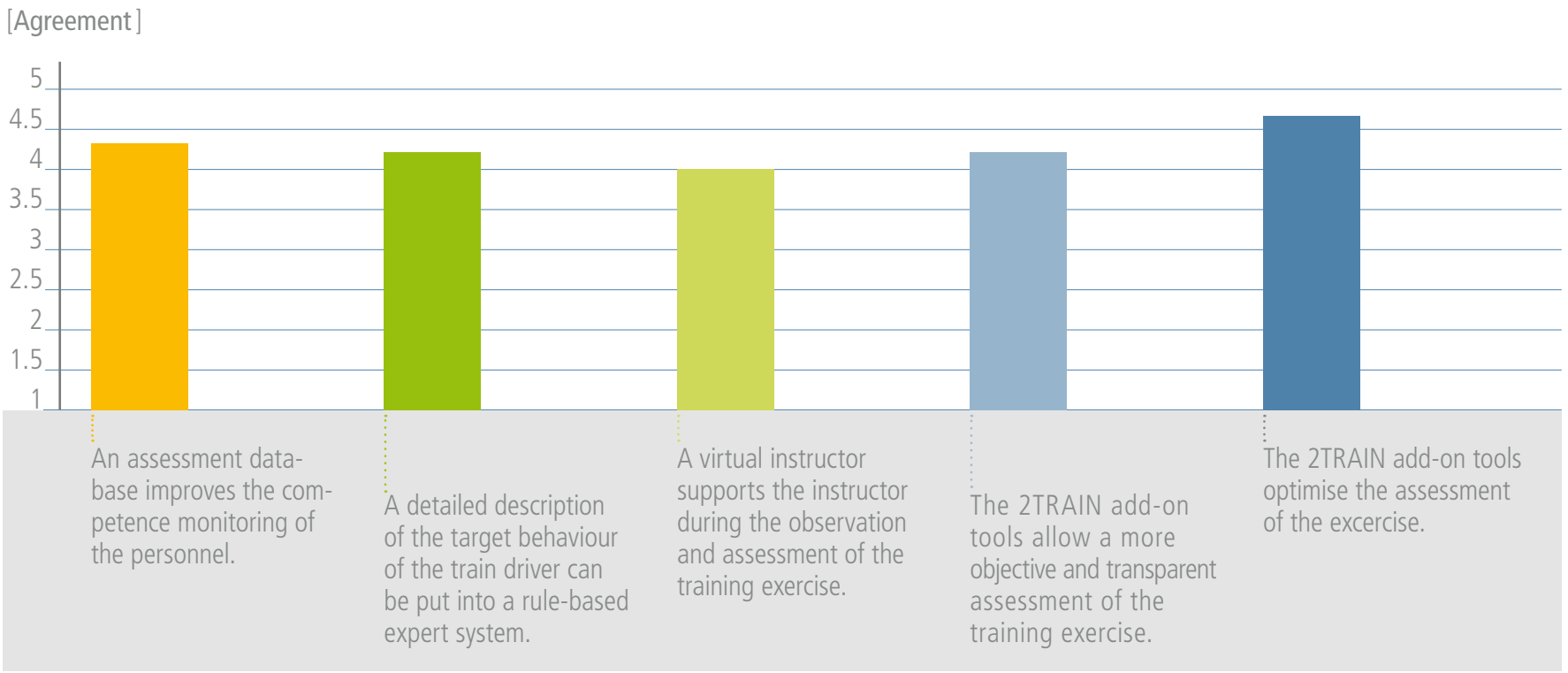
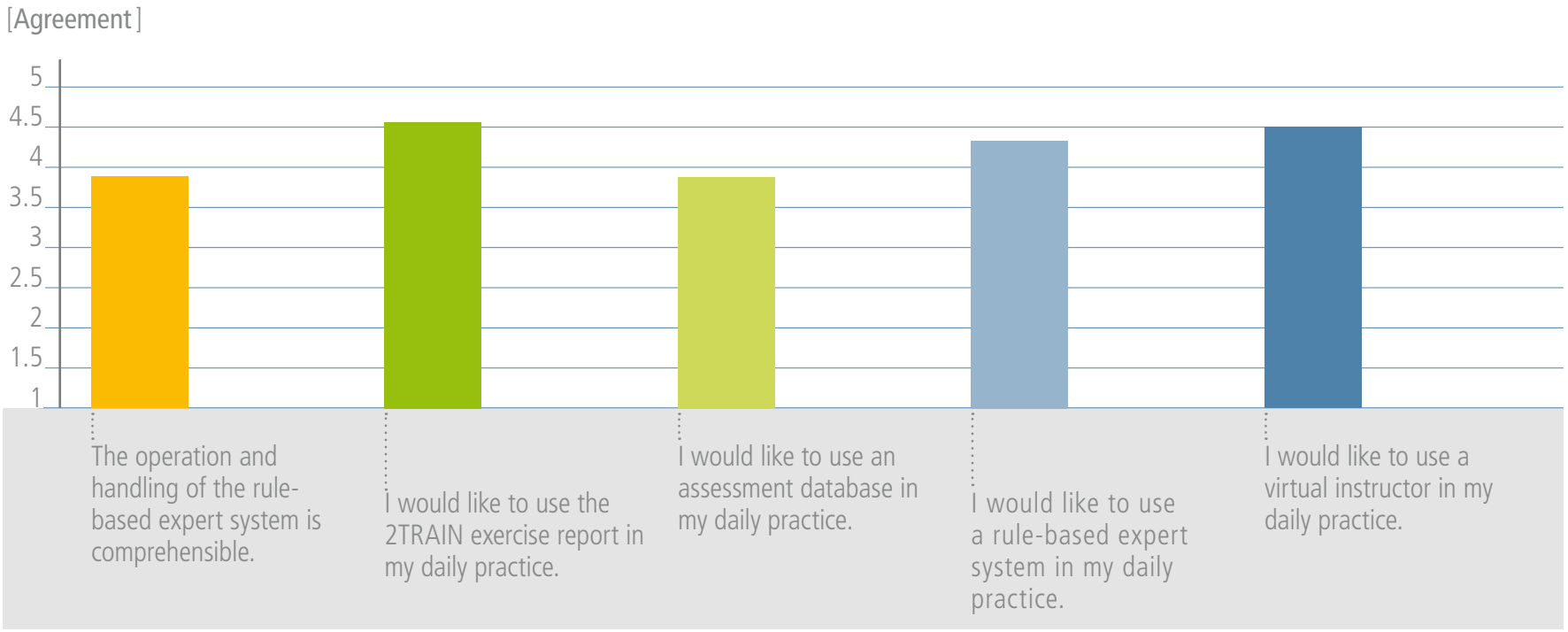


Figure 14: Usability of add-on tools



The fourth statement obtains the same general agreement as the two previous ones, but the distribution by pilots is different:

- The best results are obtained in Spain, where instructors fully agree with the statement.
- In France and in Germany, results are good, but some instructors are not fully enthusiastic.

The last statement gets a very positive agreement from all instructors. At all pilots, all instructors agree or totally agree with it. It confirms the positive opinion on the tools, which are rated quite highly when tested and used as a whole. Furthermore, five questions relating to the usability of the tools were directed at the instructors. The agreement of instructors with these statements is presented in Figure 14, which displays the average marks obtained on all three pilots.

Answers to the first statement show that the operation and handling of the ExSys is generally comprehensible. But this aspect of the ExSys does not provide full satisfaction to users, since almost a half of instructors rate it 3 („neither agree nor disagree" with the statement).
No negative opinion is put forward though and results are the same in all countries. Some instructors noted that the English interface does not facilitate the use of the tool and recommended the development of a multilingual interface.
Following the second statement, the exercise report receives a very positive opinion from instructors in all countries, since they all agree that they would like to use it in their daily practice (all rates are 4 or 5). More than half of the instructors totally agree with the statement.

The same question about the AssDB provides more variable answers:

- In Spain, results are excellent (marks are 4 or 5).
- In France, the results are good (marks are between 3 and 5, average being 4)
- In Germany, results are average (marks are between 2 and 4).

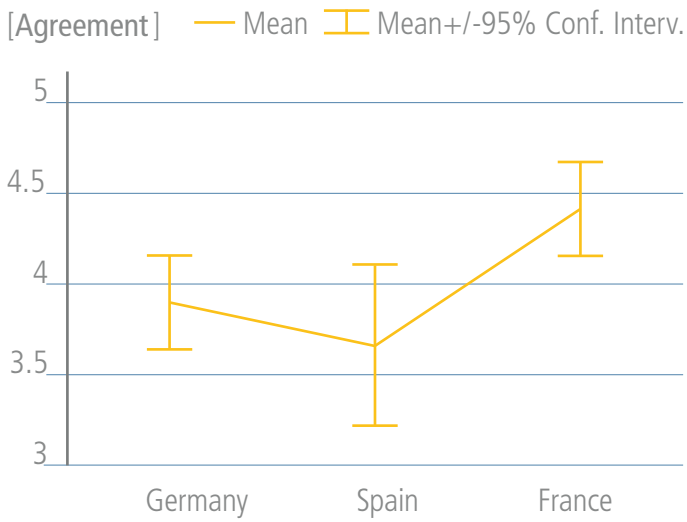
The wish of instructors to use the ExSys in daily practice gets the same positive marks as the exercise report. They all agree that they would like to use it in their daily practice (all rates are 4 or 5), regardless of the country. The wish of instructors to use the VI in daily practice gets very positive marks (all rates are 4 or 5, with the exception of one instructor in France rating it 3).
The results have shown that the add-on modules have passed the tests: the expected functionality works successfully, and the hardware and software architecture retained for the whole system is compatible to each simulator, whether it is a simple part-task simulator or a full-cab simulator mounted on a motion system, a high-speed train simulator or a light rail simulator. This result is especially noteworthy as the simulators used for the German, French and Spanish pilots had been developed before the beginning of the project by three different manufacturers. The technologies, architecture and concepts implemented on these simulators had been neither coordinated, nor aimed at the future integration of add-on modules.

Exercise report

The feedback from the train drivers is very encouraging on all pilots: In all countries, approximately 90% of the drivers agree or totally agree that the exercise report is well structured and comprehensible. This result is remarkable, since the reports are built using common tools to all platforms, with the opportunity for each pilot to adapt the content to the specific situations encountered in the scenario. These results show that both the general structure and the local adaptation to the definition of rules defined in the ExSys are validated by the drivers. The detailed exercise report also received high marks concerning its ability to increase the learning effect (see Figure 15). The French TGV drivers in particular were totally convinced that the exercise report enhances learning. All drivers across the three pilot sites were also convinced that such detailed reporting improves the quality of the debriefing session, even though the Spanish sample did not fully agree (see Figure 16).

Figure 15: Agreement on the learning gain derived from the detailed exercise report

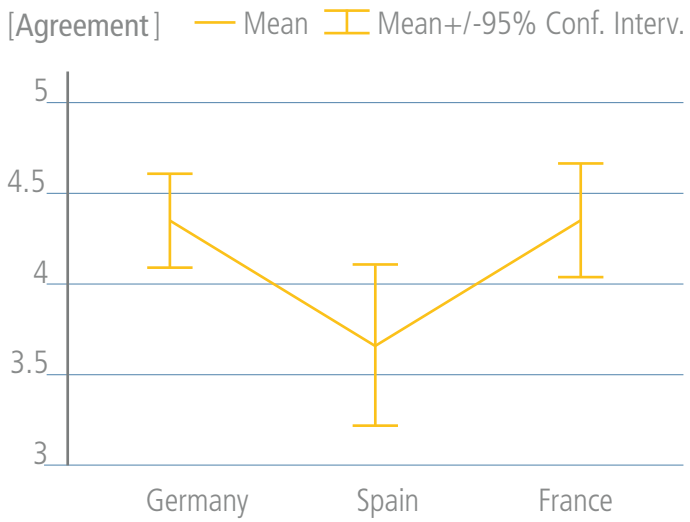
(1: totally wrong, 5: totally true)



The detailed excercise report increases the learning of the simulator excercise.

Figure 16: Agreement on the ability of the report to improve the debriefing

(1: totally wrong, 5: totally true)



The detailed excercise report supports and improves the debriefing of the simulator exercise.

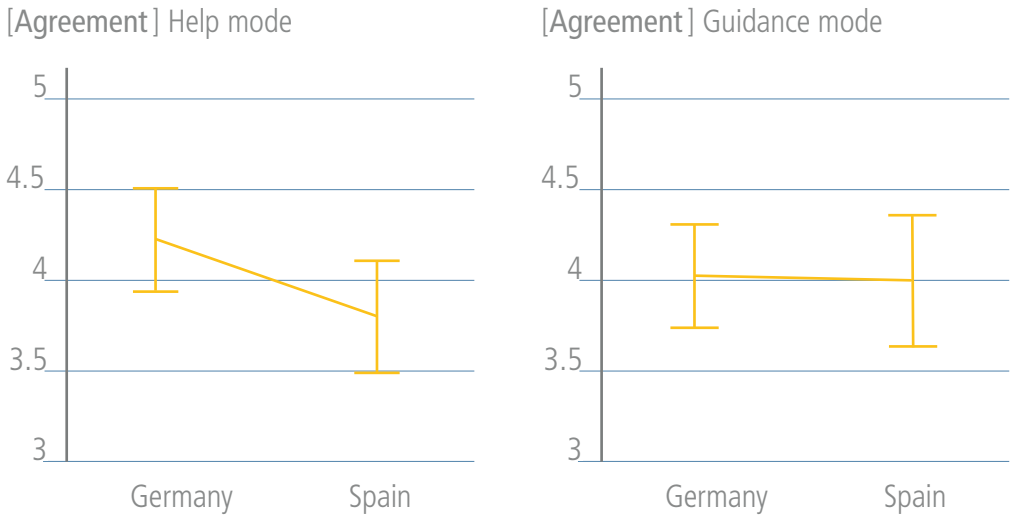
Help and Guidance mode

The Help and Guidance modes have been evaluated only in Germany and in Spain, since these modes were not in the scope of the French pilot. During the Help mode, additional information is presented to the train driver on the visual system of the simulator (e.g. feedback concerning the speed limit). The Guidance mode includes learning modules that are presented on a screen in the driving cab, giving detailed information on the correct behaviour during an upcoming event (Figure 10).

When it comes to the learning gain that could derive from a usage of the different working modes, the drivers of both samples were highly convinced of the benefit of these additional functionalities (see Figure 17).

Figure 17: Agreement on the enhanced learning gain attained by the Help modes and the Guidance mode

(1: totally wrong; 5: totally true) — Mean ⊥ Mean+/-95% Conf. Interv.



Left: The working level 'help' of the VI enhances learning.
Right: The working level 'guidance' of the VI enhances learning.

In Germany and Spain, the Help and Guidance mode is highly appreciated, since they provide a very good complement to the usual theoretical training. Therefore, the train drivers assume that these working modes will increase the learning effect as the feedback is given immediately after an error or a successful handling of the situation.

Evaluation of 2TRAIN CBT/WBT modules

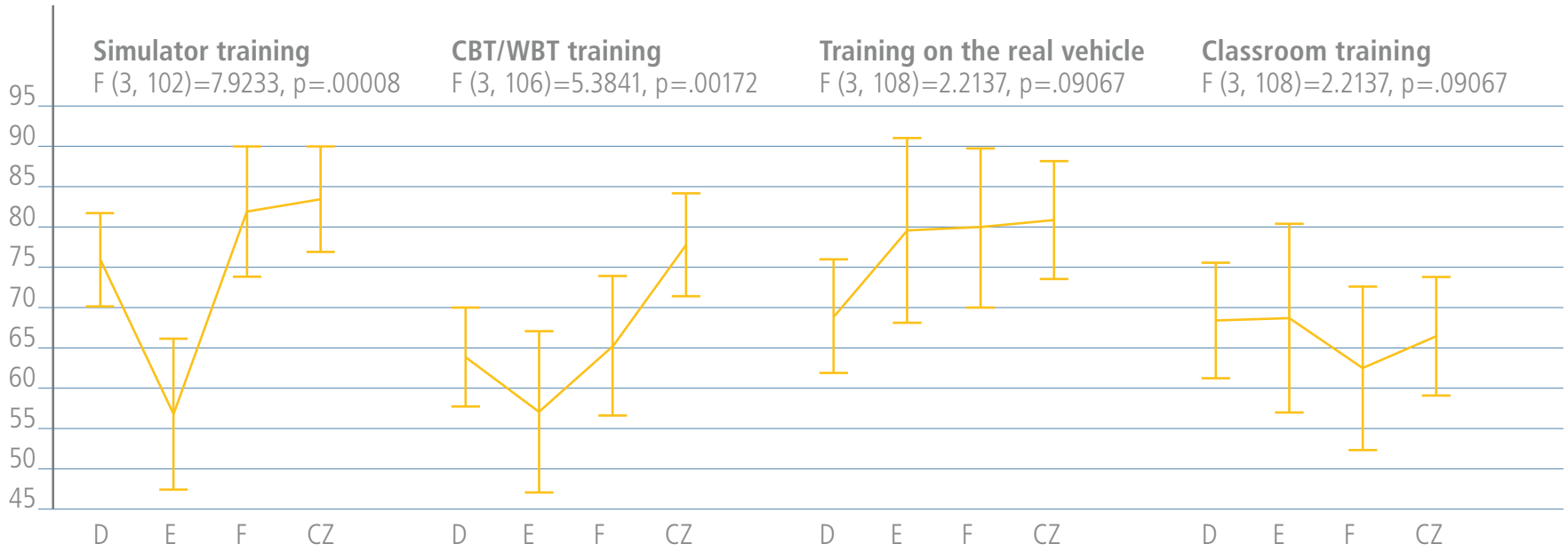
The results of the CBT/WBT evaluation show that both the German and the Czech modules are well-structured and easy to use. Even if the concepts in the Czech WBT and the German CBT were quite different, the results show that the drivers from both companies gave high marks.
In the Czech Republic the WBT was introduced as a new learning media and aims at learning. Therefore, the structure with a lot of training modules and a final test at the end is very useful. In Germany, where CBT is used for continuous advanced training and for competence checks, the concept is different. At the beginning of each module the student's knowledge is tested by some questions about the model's content. Only if there are some gaps detected, the trainees have to work through the module. Otherwise, the trainees can skip to the next module. If each topic is finished, then a final test has to be passed.
The Czech students appreciated the concept offered to them as well as the German students did with the different concept. Furthermore, it is also very important to match the right scope of a CBT/WBT content. If it is too wide, there is a risk that the students could be overwhelmed, while the scope is too narrow, it could be boring.
The results could show that the scope was chosen appropriately. The results of the question "The learned contents are important for daily work" show that in both countries the content of the CBT/WBT modules was chosen very well. Also the feedback on the question "I can put the learned content very well into daily practice" shows the well-chosen learning content in both national pilots.

Different training methods

Figure 18 shows the train drivers' ratings concerning the general appropriateness of different training methods. Whereas the French and the Czech drivers gave really good marks and the German drivers slightly lower ones, the Spanish trainees rated simulator training significantly lower. It is hard to say why, as the open answers during the final discussion showed only positive statements towards simulation. Nearly the same structure could be found related to the appropriateness of CBT/WBT modules, but at a lower level. Again, the Spanish sample gave significantly lower marks than the other three samples.

Figure 18: Appropriateness of simulator training, CBT/WBT training, real vehicle and classroom

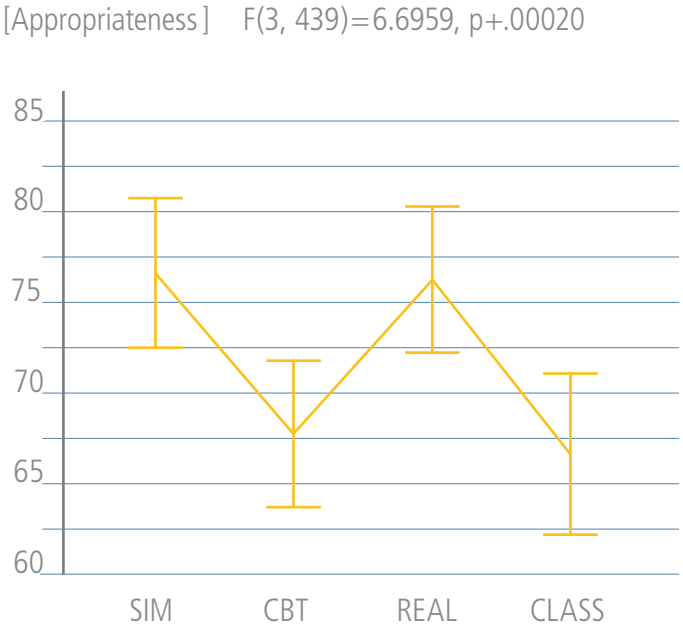
(Visual scale from 1 to 100, vertical bar shows 0.95 confidence interval)



Training on the real vehicle was seen as quite an appropriate method with slightly lower ratings in Germany, but the acceptance is clearly higher compared to training in the classroom (that might be more linked to the theoretical content). When all four training methods are compared, the simulator and the training on the real cab are favoured (Figure 19).

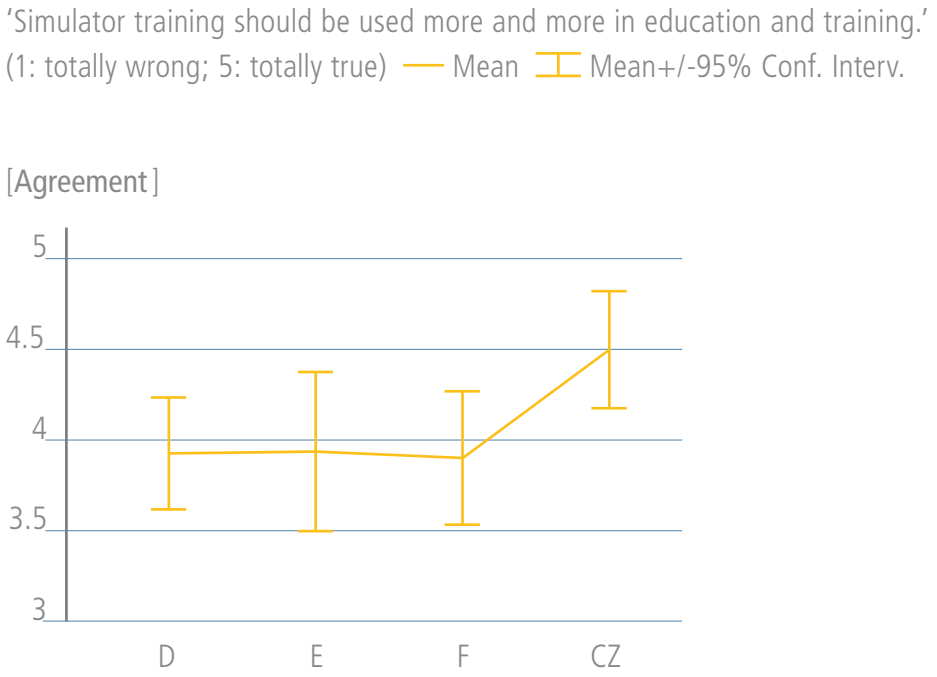
Figure 19: Appropriateness of training methods

(Visual scale from 1 to 100, vertical bar shows 0.95 confidence interval)



With the exception of some isolated opinions, all drivers that took part in the 2TRAIN demonstration activity agreed on an increased provision of simulator-based training in initial and advanced training (see Figure 20).

Figure 20: Agreement on an increased provision of simulator training



CSA results

Cognitive Style Analysis (CSA; Riding and Cheema, 1991[1]) is designed on the conclusion that there are two principal cognitive style dimensions namely the:

- Wholist: Analytic Style dimension of whether an individual tends to organise information into wholes or parts
- Verbal: Imagery Style dimension of whether an individual is inclined to represent information during thinking, verbally or in mental pictures

The CSA is computer-based and provides a more objective measure of cognitive style compared to a self-report questionnaire for example. In the context of the 2TRAIN project, the CSA had the added attraction of being available in French, German and Spanish and could therefore be used in each of those 2TRAIN national pilots and provide comparable data across each pilot.

Furthermore, the CSA has been used in related train driver research within the UK (cp. Russell & Russell, 2009[2]) and again, comparisons with the 2TRAIN populations were felt to be a useful benefit. The results for each national pilot and overall summary for the total sample population are provided in Table 3. There was no correlation found between the ratios on the two dimensions ($p>0.05$). This result is consistent with previous research. Of course, we are dealing with relatively small sample sizes within each of the three national pilots. The SNCF and Madrid samples being particularly small and therefore appropriate caution should be applied to the results. However, on the Wholist-Analytic (WA) dimension, both the DB and SNCF samples were at the analytic end of the dimension.

1 Riding, R. & Cheem a, I. (1991). Cognitive styles - an overview and integration. Educational Psychology, 11, 193-215.

2 www.rssb.co.uk/pdf/reports/research/T441_rb_final_phase2.pdf

The UK standardisation data for the CSA (Riding, 1998[3]) provides for a mean 1.25 (sd 0.45) on the WA dimension. Therefore, even for the whole sample population of N=75, the group are at the analytic end of the dimension. This has very important implications for the structure of learning material for train drivers and also has implications beyond training, into areas such as job design and human error. On the Verbaliser-Imager (VI) dimension, all three national samples fall into the bimodal category. The UK standardisation data for the CSA (Riding, 1998) provides for a mean of 1.06 (sd 0.20) on the VI dimension. Therefore, for the whole sample population of seventy-five, the group are slightly at the verbaliser end of the dimension. This has important implications for the design and presentation of learning material for train drivers.

3 Riding, R. (1998). Cognitive Styles Analysis: Research Administration Learning and Teaching Technology, Birmingham.

Table 3: Summary of CSA results

Sample	Sample size	Wholist-Analytic		Verbaliser-Imager	
		Mean	sd	Mean	sd
Deutsche Bahn	40	1.5578	0.60030	1.0637	0.15089
SNCF	20	1.5670	0.54329	0.9950	0.13371
Metro Madrid	15	1.1273	0.26078	0.9820	0.18178
Whole Group	75	1.4741	0.55593	1.0291	0.15574

Summarising the evaluation results

In general, the add-on modules got a very positive evaluation from drivers and instructors. A common remark that has been made by instructors either in the usability tests or during open discussions concerns the configuration and design of the assessment rules. The interface of the rules editor on the ExSys is too close to a programming language and requires specific skills that limit its user-friendliness. But the general concept of the tool has been greatly appreciated, as confirmed by the positive answer to the question of whether they would like to use it on a daily basis. The online GUI of ExSys has got a better feedback and is already considered by many instructors as efficient for daily use.

The participants of the pilots that included the Help and Guidance mode of VI reported that such functionality would be very efficient for initial training. The exercise report has been rated quite highly by all participants, both instructors and drivers. Hence, both the structure of the report and the accuracy of the information have received a very good feedback.

This is a proof of the real success for the whole system, since such a result requires the whole process to work properly: the design and creation of assessment rules, the collection of data for the simulators and exchanges between modules, the online analysis of the rules, the export to the database and the writing of the report. Only the proper behaviour of all modules (CDSI, ExSys, VI, and AssDB) could enable such a successful result.

5. Conclusions

Foto Source: Thomas Sturm, pixelio

Conclusions

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5.1 Impact on the development process

The successful integration of the whole 2TRAIN system on all national pilots is the real advancement in the scope of developing European standards for the coordination and the harmonisation of train driver training, mainly in terms of assessment concepts. The 2TRAIN project has proved that a common system for assessment and guidance of train drivers can be implemented on existing simulators throughout Europe, taking into account the additional constraint to use scenarios based on common situations, enriched or not by the use of CBT modules. The 2TRAIN tools can be considered as a modular package being able to interact with very different systems. This aspect has been appreciated by long-time users of simulators who participated in the 2TRAIN user forum and have shown great interest in such a technical solution being used as an add-on to an existing simulator. Beyond the purely technical success, the feedback from intended end users is a major criterion to evaluate whether the system is ready for training. Several aspects must be studied: efficiency, user-friendliness, robustness and reliability. The efficiency of the system can be analysed from two angles:

- Improvement of training sessions, which covers aspects such as the support to the instructor and the optimisation of the assessment. Feedback for these subjects has been positive. A very high rating from both instructors and drivers goes notably to the exercise report. Its common structure and its adaptation to each pilot could lead to a increased objectivity of the assessment.
- Learning effect, which is more difficult to evaluate, since such effect is barely visible when based on data from small samples of drivers and short durations of training, such as was the case for the 2TRAIN pilots.

Subjective opinions collected by questionnaires from drivers and instructors are positive though, both for the assessment and the Help and Guidance mode. The application of the Help and Guidance mode was mostly recommended for initial and refresher training.

The questionnaires on the usability of the add-on tools filled in by instructors and drivers lead to the following conclusions concerning their user-friendliness:

- The clarity of the information displayed on the exercise report has been appreciated by the drivers.
- The user-friendliness of the system as a whole is rated very highly by instructors, since sessions could be performed after a short presentation of the tools. Nevertheless, some improvements of the add-on modules are requested, notably concerning the rules editor, which is close to a programming language. Use of the local language would also improve the user-friendliness of the tools.
- The comparison of the feedback of drivers with their biographic data and experience indicates that the age and the experience with simulators and CBT do not have a clear influence on the acceptance and understanding of the tools. Hence both add-on tools and CBT modules seem adapted to all profiles of drivers.

In addition to the efficiency and user-friendliness, the usability of the system depends on its robustness and reliability:

- Robustness could not be fully stressed in the scope of the project due to the small size of the samples who have participated in the pilots. Nevertheless, the successful implementation and use on the different pilots during several weeks is a good indication that simulation sessions with these tools can be repeated without any support from the developers.
- For the same reasons, the same conclusion can be retained for the reliability of the system. In addition,

the pilots have shown that the reliability of the drivers' assessment is highly dependent on the relevance of the rules defined in the ExSys rules editor: the target behaviour must be precisely defined, which requires the testing of each situation on a relevant sample of instructors before using it for training sessions.

Throughout the development of the project, the partners have identified a number of requirements to improve the current 2TRAIN add-on tools in order to facilitate their use during the training and make it more attractive, including new functions and benefits:

- The interfaces of the modules, and notably the ExSys should be multilingual.
- More rule templates for a simpler use of the ExSys should be created.
- The interface of the ExSys should be adapted to the intended end user and not require special skills in IT science.
- The user should be able to define the rules as operational procedures and not using a programming language.
- The installation procedure for the add-on tools should be improved, so that the installation could be even more effective and easier.
- The evaluation possibilities of the virtual instructor could be extended.
- More Flash-technology should be used within the CBT modules.
- The usage of video sequences within CBT modules should be increased.

5.2 Impact on learning effects

Gagné (2004[4]) developed a systematic approach to instructional design and training. One of his instructional theories contains an attempt to structure training design in terms of so-called instructional events that are closely linked to internal mental processes. Gagné identified the mental conditions for learning based on an information processing model and created a nine-step process of training design that should facilitate learning. To find out whether the skills learned from a training programme are ever applied to the daily work often remains difficult. Effective training programmes have a performance focus, including design and different types of media that facilitate retention and transfer to the job. Applying Gagné's nine-step model to the 2TRAIN training programme could show the appropriateness of the new developed add-on tools in contrast to the situation before such systems have been implemented. The 2TRAIN simulation exercise is divided into three parts: (1) briefing, (2) simulation run, and (3) debriefing. Applying Gagné's concept to the simulator training, the first three events are addressed by the briefing. The simulation run covers the next three events, and the provision of feedback is part of the de-briefing. Assessing performance and enhancing retention and transfer to the job is exactly what 2TRAIN is about. In particular the application of the different VI working modes 'Help and Guidance' could enhance the quality of some of the instructional events. The following table displays which instructional events could be strengthened by implementing the 2TRAIN add-on tools and which have been addressed during the demonstration activities.

4 Gagné, R. M., Wager, W. W., Golas, K. and Keller, J. M. (2004). Principles of Instructional Design (5th Ed.). Wadsworth Publishing Co Inc.

Table 4: Link between the 2TRAIN add-on tools and the instructional events

Instructional Event	2TRAIN enhancements
1. Gain attention 2. Inform learners of objectives 3. Stimulate recall of prior learning	• Introduction of 2TRAIN and its objectives • Detailed briefing of the trainee by the instructor including the train type and the route • In case of self-paced learning the briefing also could be provided by the VI guidance mode
4. Present the content 5. Provide learning guidance 6. Elicit performance (practice)	• 2TRAIN simulation exercise containing several degraded and abnormal situations • Czech and German CBT/WBT modules covering broader theoretical units containing selected degraded and abnormal topics. Two situations were also part of the simulator exercise • VI guidance mode could lead the trainee through the session and provides additional pieces of information • The VI also enables adaptive training
7. Provide feedback	• VI help modus gives direct feedback on the trainee's performance • Debriefing of the trainee by the instructor on the basis of a detailed assessment report
8. Assess performance	• 2TRAIN add-ons enable automated assessment and enhance the assessing performance
9. Enhance retention and transfer to the job	• 2TRAIN simulation scenarios that are realistic, relevant and safety-critical • CBT/WBT modules that are realistic, relevant and safety-critical

In any case, reliable and valid findings of transfer-of-training effects were not possible in the context of the 2TRAIN pilots. Firstly, the 2TRAIN demonstration activities should demonstrate the feasibility and functionalities of the add-on tools. Secondly, the pilots should measure the acceptance of those tools in regard to the trainees and the instructors. It has never been intended to establish an experimental study on learning and transfer effects or to run a whole evaluation programme.

5.3 Impact on safety aspects

For a common European safety approach, training modules for specific safety related issues were developed and disseminated. Besides general driving and operational abilities 2TRAIN was to a large extent focused on crisis management competencies. The training of safety-relevant human factors in abnormal and hazardous situations was a key content in the training curricula (e.g. communication, decision making and multiple tasking). In addition, the standardisation of data (common technology and data interface), the curricula (common training contents) and the assessment procedures contributed to enhanced safety on a European level. The project enabled computer-based training to be widely used. As a consequence, the driver skills were enhanced leading to an increase in safety.

6. Guidelines for training and assessment

Guidelines for training and assessment

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6.2 Guidelines for implementing the assessment system 74
6.3 Guidelines for training models, settings and transfer of training 78

These guidelines are provided as assistance for train operating companies and training providers to adapt current training technologies, contents and models and to benefit from 2TRAIN results. These guidelines include:

- Technical guidelines
- Guidelines for implementing the assessment system
- Guidelines for training content and trained competencies
- Guidelines for training models, settings and transfer of training

6.1 Technical guidelines

The comparison with standards, the design and development processes, the technical results and the feedback from pilot studies enable the following guidelines to be proposed for the further standardisation and harmonisation of the training technologies:

- Architecture used for the 2TRAIN pilots: Standard communication library between the simulator and the add-on modules is recommended to enable the compliance of the system with all types of simulators and to favour the standardisation of training tools. The same runtimes can be used on any type of simulator. The adaptation to the existing simulator can be made by means of a dedicated interface.
- Hardware architecture: The current state of the technology makes Ethernet network the recommended standard solution for the implementation of

add-on modules. A 10 MB bandwidth is sufficient. The 2TRAIN solution enables an overall assessment, Help and Guidance system to be implemented by the simple addition of two notebooks to the network.

- Configuration of the cab: To enable interaction with the driver for "Help" and "Guidance", an additional interface must be available to the driver, to display messages (which is possible on CGI screen, or on any cab display), or also to enable controls (which requires keyboard/mouse or preferably a touch screen).

Specific guidelines can also be identified to optimise the development process and enable parallel development and integration of add-on modules:

- Define milestones for each step of development
- Define precisely the functional range of each module and the concrete requirements of the technical products
- Involve the intended end user (instructors/trainers, train drivers, and training managers of railway undertaking) strongly in the early phases of function and application planning as well as during later development phases
- Plan a phase of technical analysis and design between requirement analysis and technical development

Finally, guidelines have been identified for the use of the technologies developed within the 2TRAIN project:

- Supporting the instructor by using an automatic assessment tool and the possibility for the instructor to fill in subjective ratings and comments after each training situation make the system particularly efficient for the supervision of several trainees simultaneously. The reason is that such add-on tools prevent missing what happens with a trainee, even if the attention of the instructor is diverted to another trainee, since, even for subjective assessment, the question remains open in the GUI of the add-on tools until the instructor has answered it.

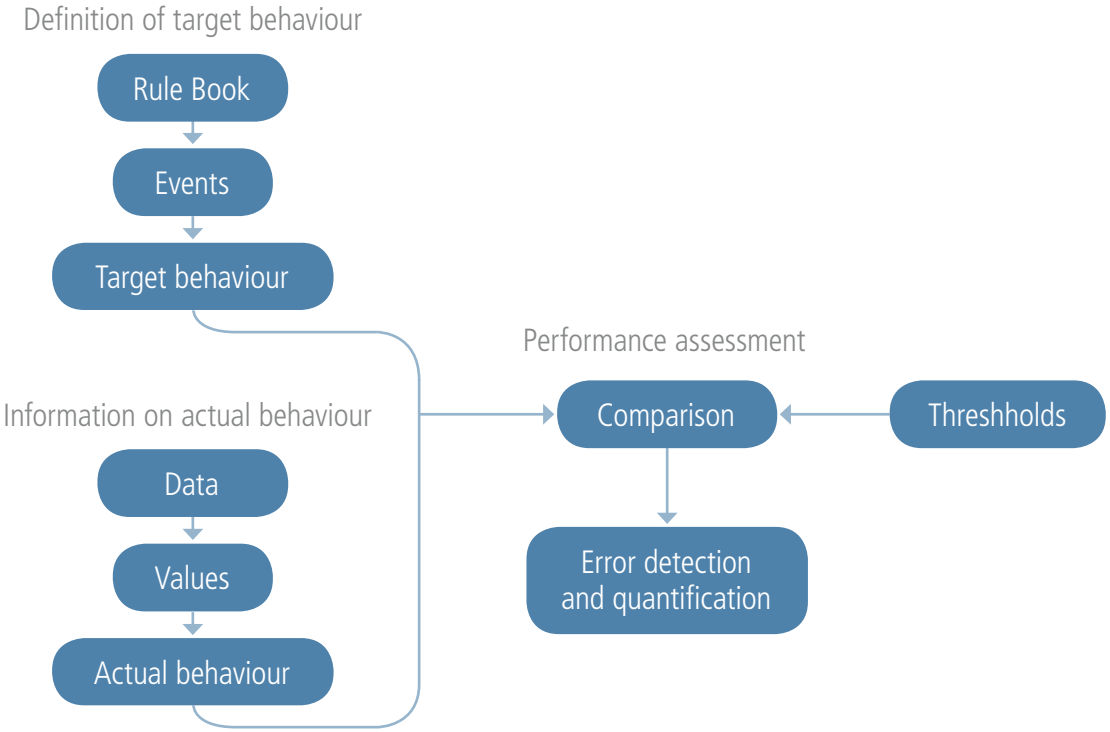
- 'Help' and 'Guidance' modes are recommended and should be focused on and tailored to initial or refreshment training.
- The relevance of the assessment and of the exercise report strongly depend on the accuracy of the assessment rules: It is highly recommended to revise each rule by submitting it to tests by several instructors, in order to check that the rule covers all possibilities of operations by the driver.

For CBT, a competence-based structure (which makes the trainee go through learning modules only when knowledge tests are failed) is recommended, notably for learning programmes dealing with operational or procedural topics. Such structure enables optimisation of the time spent by trainees on the CBT and directs the focus onto topics that require more training.

6.2 Guidelines for implementing the assessment system

For the assessment of the train driver's performance during a simulation exercise, a concept is needed that integrates the necessary data, its processing, analysis, and interpretation. On the one hand, this data concept must describe the target behaviour during specific simulator events. On the other hand, the actual behaviour of the train driver must be recorded. Finally, the actual behaviour must be compared with the target behaviour using thresholds for performance assessment.
The PERMA concept (PERformance MArker) of assessment fulfils the above mentioned requirements and consists of the following elements (Figure 21):

Figure 21: PERMA concept for the assessment of train drivers by using a simulator



Definition of target behaviour:

- Compilation of the rules and regulations that are relevant for running a train in a specific railway system (e.g. rule book, directives, speed book)
- Selection of training situations the train driver has to deal with (events)
- Derivation of the behaviour from the rules and regulations that has to be carried out by the train driver during an event (target behaviour)

Information on actual behaviour:

- Provision of the variables that reflect the driving behaviour of the train driver (data)
- Extraction and definition of the output values that describe the driving behaviour in specific events (values)
- Description of the behaviour of the train driver during an event (actual behaviour)

Performance assessment:

- Definition of criteria for the rating of deviations between target and actual behaviour (thresholds)
- Comparison of the derived target behaviour with the recorded actual behaviour and application of the thresholds
- Description and grading of the performance of the train driver (error detection and error quantification)

The basic procedure of this comparison is generally valid, but its application is unique for every event/situation of the simulator exercise. The relevant information for the assessment is provided by a data interface linked to the simulator (objective assessment of actual behaviour), the observation by an instructor (subjective assessment of actual behaviour), and an expert system that provides the ideal behaviour (target behaviour and thresholds).

The assessment system has to be connected in runtime to the simulator and receives the information about the actual behaviour of the driver through the data interface, i.e. actions on the controls, the status of the train (speeds, door status, etc.), and the conditions of the environment (route, signalling, etc.). The target behaviour of every single action is pre-defined and stored in an expert system. The data of both information sources – data interface and expert system – enter together into an assessment unit that is responsible for the assessment procedure itself. When the train driver drives under normal, irregular or abnormal conditions, he always has to respect the operational rules and regulations. The assessment unit proves whether the train driver executes all necessary actions in accordance with the rules, i.e. in accurate order, in time and precise enough, and whether deviations between actual and target behaviour occur (and how these deviations should be rated in regards to the criteria safety, punctuality, and economy). If for example the data interface sends an actual speed that is above the speed limit defined in the expert system, the assessment unit detects and rates the extent of speeding.

Deviations from the target behaviour represent a poorer performance. For the assessment of the trainee, it is crucial to weight possible deviations from the target behaviour. If the mandatory behaviour is highly relevant for safety, it has to be weighted seriously. If the ideal behaviour is more a 'should' than a 'must', an advice to the trainee may be enough as feedback. If thresholds are defined for the assessment values, different error levels for the actual behaviour of the train driver can be allocated (e.g. advice, medium error, safety-relevant error). Often, the thresholds have to be specified by an expert group as the rules and regulations of the train operating companies give no definite threshold values (e.g. for speeding).

6.3 Guidelines for training models, settings and transfer of training

As the former sections show, the 2TRAIN assessment and training system could realise a significant impact on the learning effects and facilitates the conditions for a transfer effect of the learned content:

- Enhancing the quality of assessment (accuracy, level of details)
- Enhancing the quality of post-training data
- Enhancing the quality of the debriefing due to a detailed assessment protocol
- Enabling the link from simulator-based training to the competence management system
- Enhancing the quality of feedback during the training (VI Help mode)
- Enabling adaptive training sessions and the implementation of enhanced reality scenarios
- Using the simulator as a self-paced training method (VI Guidance mode)
- Facilitating training evaluation

In order to reach an improvement of the training system some guidelines should be made here for an optimal use of the enhanced functionalities of the simulator, such as the fact that introducing the use of a driving simulator in a whole training curriculum changes the organisation and the pedagogy; new requirements appear, from the trainee's point of view and from the instructor's point of view.
In order to provide valuable feedback and to enhance potential transfer effects it is necessary to make appropriate use of the virtual instructor. The demonstration activities could show that the main advantage of the VI Help mode is to give direct feedback to the trainee during the simulator session. As this feedback should not distract

the trainee, it is recommended to implement the Help mode only during those training courses where errors are likely to occur, i.e. associative phase and knowledge compilation stage respectively.
In later stages of education or in regular advanced training courses, the application of the Help mode should fade out and the assessment mode should be used in the first line.
The Guidance mode has a twofold application. Firstly, the Guidance mode can be provided in combination with the Help mode and thus enhance the feedback. Secondly, it has a strong instructional focus and could have the function of gaining attention and informing the trainee of the upcoming events in the cabin and during the session.
The second point is especially appropriate in case of self-paced learning or in cases where one instructor is responsible for more than one trainee at the same time.
The exercise report that was designed within the frame of 2TRAIN is modularly structured. The different parts can be individually chosen and thus adapted to the training needs.
It is the decision of the training manager how detailed the report should be. The demonstration activities could show that at least the graphical overview and an overview of the errors should be part of the report. In case of self-paced learning, the level of details could be higher in order to enhance the feedback quality.
Storing the performance measures in an assessment database enables a widespread use of these data. Concerning transfer measures, the data should be compared to at least other training sources, like the results of CBT/WBT modules or theoretical classroom training, in order to broaden the assessment focus. In a further step the training managers should link the assessment database to the overall competence management system to guarantee an optimal use of the data. In this context the 2TRAIN training system is also in line with the demand of a safety management system (SMS) as stated in the European Safety Directive (2004/49/EC), in which the training of staff is an essential element. In this context, train drivers are supposed to have

appropriate practical and theoretical knowledge, experience and skills to perform activities according to the standard expected and to carry out safety-critical work. Their competence should be regularly evaluated and deficiencies should be addressed through training.
Providing automated online assessment enables the training managers to further develop the simulator and to introduce adaptive training scenarios and enhanced reality sessions. This is a necessary precondition for an optimal use of the simulator as a training and assessment tool. Nevertheless, the role of new technologies in the training process needs to be clarified. It should be clearly defined for which contents new technologies are appropriate and which technologies should be used in each case. It should always be kept in mind that the core of training programmes is not the technology, but the didactics of the curriculum.

7. Recommendations

Foto Source: Gerhard Fraßa, pixelio

The outputs of the 2TRAIN project are potentially of great significance to the European rail industry. This was aptly demonstrated by the high level of interest in the add-on tools and the 2TRAIN assessment concept demonstrated at the 2TRAIN user event in Hamburg.
However, one event alone is not enough to disseminate the learning and understanding gained through the project into the industry. In particular, efforts should be made to share findings with national operators that are not currently using CBT/simulator technology. What is required is a robust communication strategy for 2TRAIN that can have quantitative measures applied to it at key future milestones.

Improvement of add-on tools

The further development and improvement of the add-on tools and the assessment concept is strongly recommended. These improvements should especially focus on the facilitation of their future use by end users, e.g. easy rule creation, optimised usability.

Future research on training models

The 2TRAIN project has proven the functionality of the add-on tools and also user acceptance of the tools. However, what is required now is research that explores the optimum use of the training technology for the variety of audience („novice"/„expert") and variety of uses (initial training / refresher training / assessment). Such research would build on 2TRAIN findings on assessment concepts, user acceptance, cognitive style, and instructional design and develop national pilots to measure transfer-of-learning.

However, the research should go beyond the 2TRAIN remit to consider the relationship between different training methods and media to optimise train driver training and assessment. It should seek to answer questions such as „What is the optimum time for a simulator scenario (training vs. assessment)?" and "How many safety-critical events should a simulator scenario contain?"
Such a research design should consider the 2TRAIN findings on cognitive style, in particular considering the structure and style of training content. The potential performance differentiation between Imagers and Verbalisers using simulators and CBT should also be assessed. The approach of cognitive styles offers an explanation for human error, differences in decision making and bottom-line performance.

Future research on transfer-of-learning to the workplace

New technologies offer new training opportunities that also require new didactical approaches. New technologies offer a wide range of new assessing and testing methods, but further research is still needed to specify the optimal role of new technologies for driver assessment and testing.
Another central research gap is the lack of evaluation studies covering transfer of training effects, especially in the railway area. The assessment database provides valuable data as input for transfer studies, but it is highly recommended to link this data to driving performance measures in the real vehicle, i.e. the daily work environment.
The ultimate measure of the success of technology-based training methods will be the extent to which they support on-going competence and performance in the workplace. This requires a longitudinal research design that provides the link between training (initial and refresher), assessment

and actual job performance. The active engagement of railway operators and trade unions is the key to success. In addition to the measurement of transfer-of-learning to the workplace, such research should also consider the effect on companies' performance and how the financial cost of technology can be optimised.

Further cooperation with railway stakeholders

Future research requires the active support of railway operating organisations and trade unions. In addition, in the era of a more integrated European railway network, such research should actively engage bodies such as the Union Internationale de Chemins de fer (UIC) and the European Rail Agency (ERA).

Quotes on 2TRAIN

Foto Source: Thomas-Max-Müller, pixelio

"CER fully supports the 2TRAIN project. The development and evaluation of computer-based training systems for train drivers could give significant benefits for the current simulator training activities. In this way, a better quality of training should increase the level of safety, in particular for cross-border services. This is fully in line with the implementation of Directive 2007/59/EC for improving the recognition of train driver competences all over Europe. This is very important for operators for organizing their services according to the needs of the European rail market."

Jean Paul Preumont Senior Policy Advisor

CCFE·CER·GEB
Communauté des Chemins de Fer Européens
Community of European Railways
Gemeinschaft der Europäischen Bahnen

"The Directive 2007/59/EC also lays a focus on simulator usage for examining the application of operational rules and driver performance in particularly difficult situations and this is one of the key objectives in 2TRAIN. The 2TRAIN assessment system certainly has remarkable potential to enhance the capabilities of existing simulators and thus to update the existing technology. In addition, this development might have a positive effect on practicability, reliability and mutual acceptance of assessments in an international context."

Olaf Mette Project Officer Interoperability

European Railway Agency

"The 2TRAIN project has opened my eyes to what can be achieved when we all work together as one. In particular, the virtual instructor is a superb accomplishment which can be used on simulators manufactured from a range of suppliers. This in itself helps to reduce costs and increases flexibility for industry stakeholders wishing to advance their training media."

Roger Luckins Rail Safety & Standards Board

"It is very good to see – among the many technology oriented rail research projects – an excellent European project focussing on the human factor in rail operations. In order to achieve the vision of a well integrated and well performing European railway system, the human performance should be well highlighted as a key factor within all train operations. Addressing the many differences in language, culture and education will make a major contribution to the performance and the safety of the rail system. The 2TRAIN project was built on the knowledge and experiences of many of the important players from all over Europe, from major cross-border operators to national railways and local rail based operators, supply industry and other experts. It brought us a big step forward in the field of harmonising and coordinating the education of train drivers."

Dennis Schut EU Research Manager
International Association of Railways

"I felt there was little place for an automatic element to the assessment or training of our train drivers. The trainer participation with and observation of the driver was so important for me, particularly in observing the quality of the driver's performance and any potential behavioural or human factor issues, that I couldn't omit it.
However, the 2TRAIN project has shown me that it is possible to combine both; making it possible to save some time for the trainee as well the trainers, by gathering both quantitative and qualitative data simultaneously."

Malcolm Cook Chairman

UK RAIL INDUSTRY
Simulator Users Group

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

PRIORITY FP6-2005-Transport-4: Sustainable development, global change and ecosystems
Project number: 031324 | STREP
Project duration: October 2006 - September 2009

2TRAIN

SIXTH FRAMEWORK PROGRAMME