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EUDD*plus* – a driver's desk for Europe

A project known as "EUDDplus" is one of those being funded under the European Union's Sixth Framework Programme for Research and Technological Development. It has been aiming to progress beyond what was achieved by the earlier projects of "EUDD" and "MODTRAIN/EUCAB". EUDDplus represents a harmonisation milestone on the way to devising the cab of the future, from which trains will be driven throughout Europe.

For the first time, EUDD*plus* has provided an opportunity for reviewing all the ergonomic criteria drawn up for driver's desks in the pre-competitive environment and in operating conditions close to reality. The EUDD*plus* project started with the functional description of a European driver's desk, inserted it in a prototype of the latest generation of multi-system locomotives from Alstom (the "Prima II") and tested its suitability in a field test.

The lead role in the project was entrusted to a Berlin-based agency known for short as "TSB-FAV" (or in full as "TSB Innovationsagentur Berlin GmbH - Forschungs- und Anwendungsverbund Verkehrssystemtechnik"), and there were 17 active partners in it – from academia, manufacturing and railway operations. Train drivers from ten European countries participated in the practical tests with the Alstom locomotive, which were held at Siemens' test centre in Wegberg-Wildenrath.

1 Project aims and strategic approach

1.1 Aims and presentation of results

In the field of civil aviation it has been possible for some considerable time for pilots to fly various types of aircraft without needing to undergo extensive training on each one. This is thanks, inter alia, to the existence of uniform principles of cockpit design. The European Union (EU) has now set itself the target for the near future of creating a similar situation for the drivers of railway vehicles too. To do this, it wants to achieve standardisation and harmonisation throughout Europe of the functional design of locomotive cabs, including ergonomic aspects' assessments. It was thus only logical for the EU to include a funded project to this effect in its Sixth Framework Programme for Research and Technological Development ("FP6"). That project has the full title of "European Driver's Desk Advanced Concept Implementation – Contribution to Foster Interoperability, 2006-2010" or "EUDD*plus*" for short.

The EUDD*plus* project is building further on the results of two projects that preceded it:

- ▷ EUDD (European Driver's Desk, 2001-2003), and
- ▷ MODTRAIN/EUCAB (2004-2008).

By the time they reached their conclusions, both of those projects had arrived at functional demonstrators of different concepts for driver's cabs devised in accordance with ergonomic points of view. These were embedded in simulation environments, where they were tested by a number of train drivers from various European countries in terms of functionality, mental stress and suitability for their intended purpose.

One of the significant advances with the EUDD*plus* project is that it moved out of the simulation environment for the first time. A train driver's workplace, which had been developed in accordance with the operational requirements specifications (ORSs) defined in the new UIC Leaflet 612-0 [1], was integrated in a real railway vehicle (the prototype for Alstom's new multi-system locomotive, the Prima II). This was subjected to a programme of extensive running tests at the end of 2009 to determine its usability at the Siemens Test and Validation Center in Wegberg-Wildenrath (PCW) in conditions close to those pertaining on real railway lines.

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Dipl.-Ing.
Lutz Hübner
Member of the scientific staff
TSB Innovationsagentur Berlin GmbH
Research and applications section
lhuebner@fav.de

Denis Miglianico
Senior engineer for ergonomics,
Head of HMI network
Alstom, Villeurbanne
denis.miglianico@transport.alstom.com

Dipl.-Psych.
Christina Karsten
Member of the scientific staff
Institut für Arbeits- und Sozialhygiene (IAS)
Research section
christina.karsten@ias-gruppe.de

Dipl.-Ing.
Matthias Barta
Member of the scientific staff
Institute of Managements science
Human factors working group
Vienna University of Technology
barta@imw.tuwien.ac.at

Dipl.-Ing.
Xavier Zubillaga
Member of the scientific staff
Institute of Managements science
Human factors working group
Vienna University of Technology
zubillaga@imw.tuwien.ac.at

1.2 Holistic approach

The project was structured in such a way as to be able to handle the following key factors (and others) effectively: modularisation, standardisation, harmonisation and life-cycle costs (LCCs). One key aim was to speed up European approval processes. The project team with its interdisciplinary composition worked together on the basis of an agreed common approach to develop a new culture of cooperation between manufacturers, railway operators, research facilities, trade associations and approval authorities.

The manufacturing side was represented by the system manufacturers of Alstom, Siemens, Bombardier and Škoda as well as the subcontractors of Deuta-Werke, EAO Lumitas and W. Gessmann. The Czech Railway (ČD), the rolling-stock maintenance division of the Hungarian State Railway (MÁV-GÉPÉSZET) and the production division of the Austrian Federal Railways (ÖBB) formed the ranks of railway operators who were integrated in the project directly. The research contingent in the EUDD*plus* project was provided by the IAS ("Institut für Arbeits- und Sozialhygiene Stiftung"), the "Institute of Managements science, Human factors working group" at Vienna University of Technology, AustriaTech (the "Austrian Federal Agency for Technological Measures") and UPC (BarcelonaTech University). The project as a whole was coordinated by the TSB-FAV, as mentioned above. The International Union of Railways (UIC) and the Union of the European Railway Supply Industry (UNIFE) were also members of the project consortium and they proved their value in establishing further contacts. Manufacturers, railways, standardisation bodies and approval authorities were indirectly involved in the project through so-called user platforms.

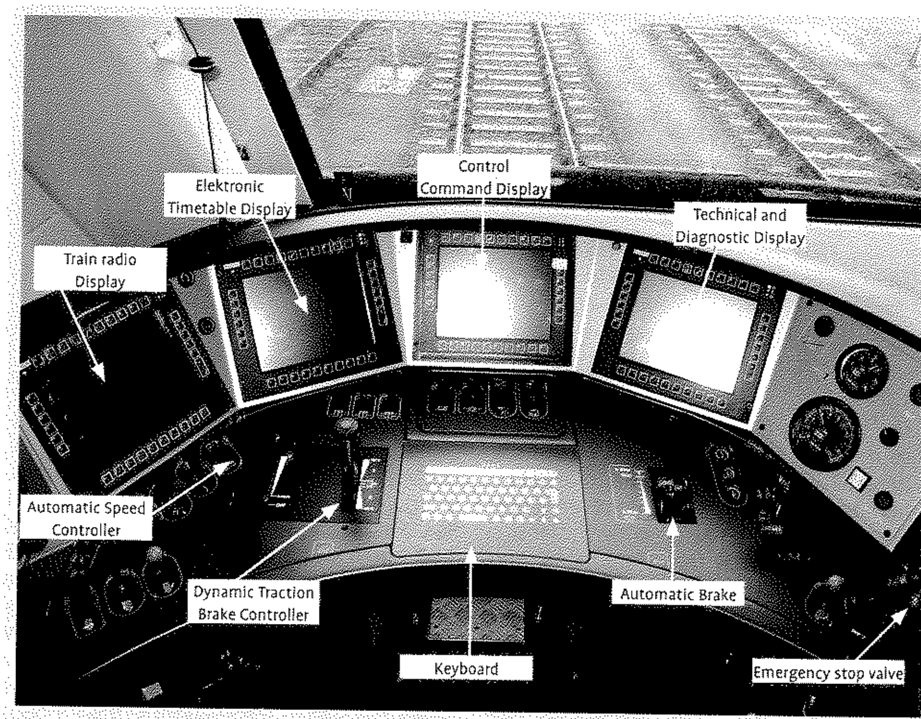


Fig. 1: The controls on the EUDDplus desk *(source: Alstom)*

2 Functionality of the EUDD*plus* concept

2.1 Specifications

The EUDD*plus* driver's desk is based on UIC Leaflet 612-0, which defines the driver/machine interface for electric and diesel multiple units, locomotives and driving trailers and, in particular, defines the functional and system requirements for a driver's cab understood as a harmonised human/machine interface.

It was a four-system locomotive (one intended for both freight and passenger trains) that was chosen for integrating the proposed driver's desk.

2.2 Hardware

The decisive factor for deciding on the arrangement of the components on the desk was the nature of the need for using them when driving a train. The driver's controls (Fig. 1) were positioned in such a way that anyone with a body size ranging from the 5th percentile female up to the 95th percentile male can reach them. Another challenge was that there were more than 25 controls needing to be arranged on the desk ensuring that operating them would not cause an extraneous element to be activated by mistake. Yet another constraint was that their arrangement shall not hinder access to the pushbuttons positioned along the sides of the displays.

The elements for operating some of the functions were grouped together in functional modules and arranged sequentially on the desk to make it easier to find them, for example: door controls, continuous automatic train control, change of direction and master switch + pantograph. This arrangement was coordinated with the functional properties of the train, for instance with the release of the left-hand doors positioned on the left, locking all doors in the middle and the release of the right-hand doors on the right.

The various shapes of the controls reflect the different functions executed by them. Some of these are self-explanatory, such as the pantograph control in a shape resembling the top of a pantograph. The intention was that all the elements would contribute to reducing the cognitive workload placed on drivers in stressful situations.

One central question was the validation of the decision to position the driver's brake valve to the driver's right. A number of European railways have traditionally had the driver's brake valve on the right and the dynamic driving/braking control lever on the left, whereas others railways have had them precisely the other way round.

All the controls have now been standardised on the EUDD*plus* desk in terms of both their shape and position. How they transmit their commands and how they react to inputs have also been standardised. In the case of the combined traction/braking control lever, selecting whether it is a tractive or braking effort that is to be applied always depends on the position of the lever. The air brake and the automatic traction and braking control lever are also adjusted as a function of position. If a driver tries to operate the combined traction and braking control lever and the driver's brake valve at the same time, it is automatically the one resulting in the higher braking force that has priority. In such a situation, the locomotive's brake computer considers the maximum permitted adhesion value of the frictional connection between the wheels and the rails. An ergonomic appraisal was made of how the train drivers cope with these standardised reactions from the vehicle systems.

2.3 Software

The EUDD*plus* desk has four different cab displays integrated in it with different operational functions (Fig. 2).

The user guidance, the selection of the screen contents and the input of data have been harmonised and optimised for each of the individual displays. The following were the principal considerations:

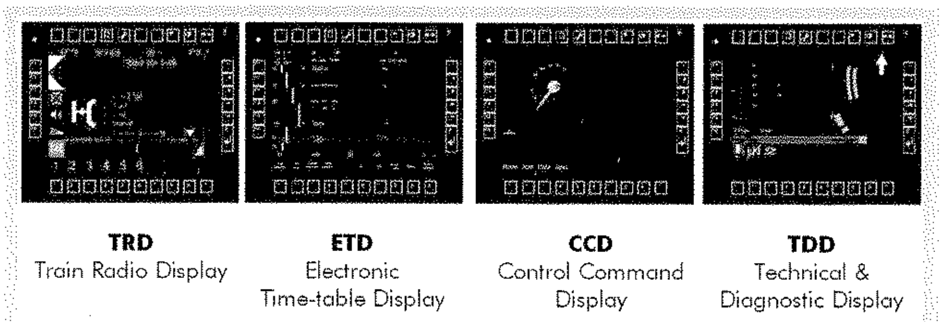


Fig. 2: The displays incorporated in the desk *(photo: Alstom)*

- ▷ The presented information is to be limited to what the driver needs while driving the train. Messages requiring no action from the driver (such as defective toilets) ought not to be shown;
- ▷ The design of the user interfaces and the user guidance by the software ought to be uniform to ensure logical operations on all four displays;
- ▷ The quantity of information to be presented ought to be minimised and ought also to be compatible with the actions being performed by the driver at that particular point in time;
- ▷ The indications on the screens ought to permit simple use of the functions shown;
- ▷ Information must be clear and uncluttered;
- ▷ The time required for assimilating the information ought to be minimised. That also applies to the number of activated buttons and the system's reaction time; and
- ▷ Functions which the driver does not need while driving the train ought not to be displayed.

In future, a redundant mode between the various displays is going to lead to greater availability.

3 The Prima II multi-system locomotive as a test platform

The Prima II locomotive recently developed by Alstom (Fig. 3) is equipped to operate with four different catenary voltage systems. The Prima II prototype, which was made available for the EUDD*plus* field tests, is equipped with ETCS Level 1 and 2 and has been designed for a maximum speed of 140 km/h when hauling freight trains and 200 km/h when hauling passenger trains. Detailed information about this locomotive can be found in a separate article in this issue of the RTR.

Given the size of the Prima II's driver's cab, no difficulty was encountered in integrating the EUDD*plus* desk on its left-hand side. In accordance with UIC Leaflet 612-0, the driver's cab has been arranged in such a way that the desk could also be integrated in the middle or on the right-hand side of the vehicle.

The desk includes a display for ETCS. It follows from this that all the train-protection systems that use the specific transmission module (STM) can be shown without the need for an additional display. The integration of further train-protection systems not using STM would be difficult from an ergonomic point of view. In such a case, a centrally positioned desk would be the better solution, since the central section of the driver's desk can easily be extended (UIC 612-0, section 3.3.2.4 on the potential for extension for inclusion of existing train-protection systems [1]).

If the locomotive is being driven from an auxiliary or secondary desk, the driver ought ideally to have one hand free and to be able to use their other hand for the combined traction and braking control. In this situation, the automatic vigilance device is operated by foot.

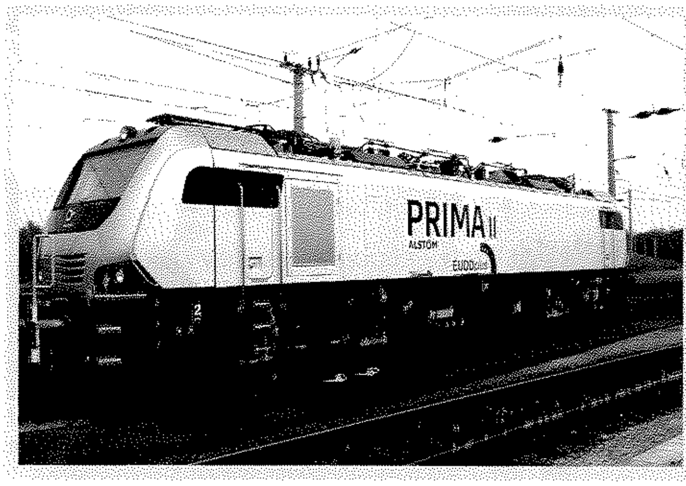


Fig. 3: Alstom's Prima II multi-system locomotive PRIMA II *(photo: Alstom)*

4 Field tests

4.1 Test persons

A total of 17 train drivers from ten European countries (Austria, Belgium, Czech Republic, France, Germany, Hungary Italy, Netherlands, Slovenia and Switzerland) participated in the EUDD*plus* field tests at the PCW. Six of the participants had also been through the simulator tests in the context of the MODTRAIN/EUCAB project. The authors would like to thank them wholeheartedly for their participation in the tests once again here.

4.2 Test scenarios

In order to try out the use of the EUDD*plus* desk in conditions close to reality, six scenarios were drawn up for the field tests and these required the drivers to deal with various driving situations making use of the cab displays. Each driver was given individual training on a simulator before embarking on the real test runs. This was followed by the so-called "Scenario 0", which gave the test subjects the opportunity of familiarising themselves with the locomotive cab, running round the large test ring, T1, several times without any data being recorded. The actual test run began with assessing how the drivers managed the cab in normal operational situations at speeds of up to 120 km/h in different lighting conditions, namely in daylight (Scenario 1) and in darkness (Scenario 2). These two scenarios included emulations of certain operational situations, such as approaching a signal at danger, driving on dead sections, changing from one voltage system to another and the transition between two different train protection systems (the case in point being the change between ETCS Level 1 and 0). The drivers were also required to carry out train-preparation activities, such as testing the brakes, the automatic vigilance system and the ETCS system as well as entering the train data. Scenarios 3 and 4 were used for simulations of particular occurrences, such as compressor failures and emergency braking. Scenarios 3 and 4 were run on the small test ring, T2, with a maximum permitted speed of 85 km/h.

The test series finished with Scenario 5, which had been designed to test the quality of auxiliary and secondary consoles during shunting manoeuvres on test track T5 with gradients of up to 40‰. The fact that the PCW had been chosen for the field tests rather than any real operational railway lines offered the advantage of presenting all the scenarios in the same way, which created favourable conditions for making comparisons.

4.3 Organisation of the test runs

In order to simulate a realistic operational situation and to check the standardised position of the driver's brake valve even with a longish main brake pipe, a freight train was used for the test runs on the T1 ring. This was comprised of the test locomotive and nine unloaded Sgns-type container wagons, capable of running at up to 120 km/h. This test train had a length of 197 metres, a total mass of 269 tons and a braked weight percentage of 103.

In addition, six sets of LED signals were set up around the big test ring. Their positions were fixed, but it was possible to change the signalling aspects (Fig. 4). These were used as home and distance signals and also for indicating permanent speed restrictions, neutral sections, voltage-change sections and changes in the train-protection systems. This made it possible to run trains over routes of 50-60 km with varying operational limit conditions by running several rounds of test ring T1, which has a circumference of 6 km.

4.4 Test methods

The drivers were asked to evaluate the desk after every time they had used it. For this purpose, standardised questionnaires were used, concentrating on ergonomics and usability. More specifically, the questions dealt with ease of recognition, accessibility and simplicity in operating all the important controls and also the presentation, legibility and comprehensibility of the displays.

The contrast conditions in the cab were measured using a luminescence camera system. A mobile eye-tracking system was also used for recording the drivers' eye movements during Scenarios 1 and 3. This provided data from which it was possible to check whether or not the drivers looked for all the controls in the places envisaged for them and how quickly they noticed changes in the displays. Combining these findings with the subjective views expressed by the drivers in replying to the questionnaires, it was possible to recognise driving strategies and to derive indications as regards the positioning and handling of the most important controls and displays.

5 Test results

5.1 Overall impression

The drivers' general judgment of the desk was a very positive one. They especially welcomed the colour scheme of the metallic blue surface, which reduced unwanted reflections. The design of the sun visor in combination with the colours used was also found to help in suppressing annoying glare. These views were found to tally with the luminescence measurements and the contrast values calculated from them.
The test drivers also reported that they found their proposed new workplace much more comfortable on account of the shape of the desk, the arrangement of the push-buttons and switches, the displays chosen and, as already mentioned, the colour scheme.

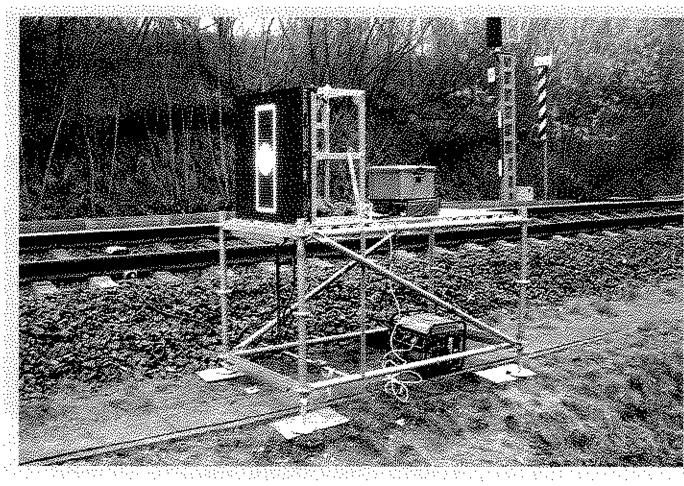
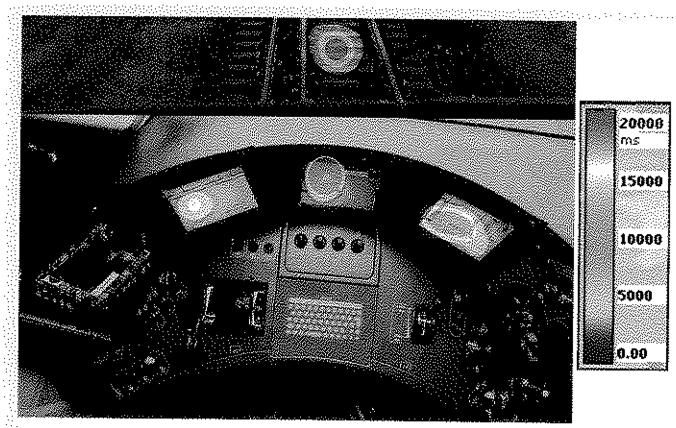


Fig. 4: A movable signal on the PCW test ring T1 (photo: EUDDplus)

5.2 Hardware

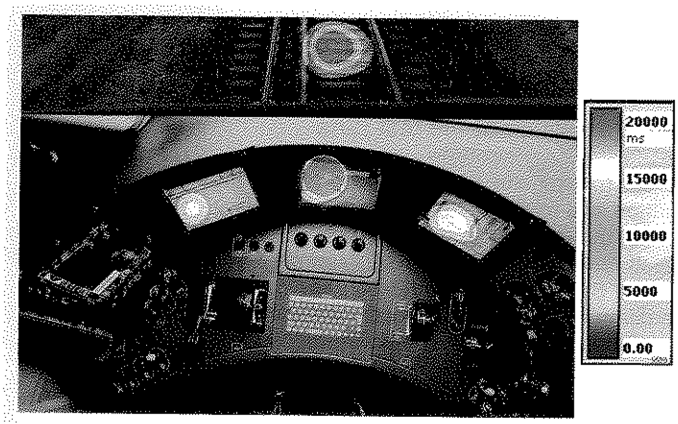
One of the aims of the new design had been to reduce the number of controls present on the desk. Those controls that remained were grouped together in sequential or functional modules, making it easier to operate them intuitively.

In general terms, the drivers were happy with the arrangement and shapes of the controls on the desk. The test drivers also felt that the aim of intuitive operation had



→ 41,6 %: Track
→ 31,9 %: TDD
→ 16,0 %: CCD

Fig. 5: Breakdown of driver eye movements during a voltage-system change (source: EUDDplus)



→ 46,1 %: Track
→ 8,6 %: TDD
→ 29,1 %: CCD

Fig. 6: Breakdown of driver eye movements during the entire test run (source: EUDDplus)

been reached, which was confirmed by the measurements of their eye movements. During the test scenarios, they did not stare at the desk any more than had already been observed in other cabs. Despite this generally positive appraisal, there were proposals for improvements on points of detail, especially as regards the accessibility of controls. The drivers would have liked to have some of the modules repositioned, so that other controls were no longer in the way when attempting to use them.

One subject that was frequently discussed in connection with the controls was the best design of pushbuttons – in other words whether they should be flush with the working surface or somewhat raised. The drivers expressed the preference for flush-mounted pushbuttons, at least in the central part of the desk, and the reason they gave was that there was a better feedback when using them. The drivers, however, preferred raised buttons around the edges of the desk, since it was easier to feel for them and operate them while driving, without needing to have them within their field of vision.

5.3 Contents and monitoring of displays

Given that many of the operator functions had now been implemented in the software, one of the central issues of the evaluation was the test drivers' reactions to the newly designed screen interfaces that were now used for both monitoring and interaction. The drivers were on the whole in favour of the distribution of the information over the four displays, the colours chosen and the basic structure. There was only one point rejected by the majority of the test drivers and that was the presentation of the electronic timetable sheet, which they felt to be poorly structured. Some also criticised the software implementation, in that they found the font size too small in places and that there was too much redundancy in certain items of information.

The repetition of certain operational situations several times over as scheduled in the scenarios offered not only the opportunity of analysing the principal contents presented in the displays but also of evaluating the intuitive operation and the logic of the display navigation during special situations. Records were also produced of parallel or sequential interactions with the hardware elements. A good example in this respect is the change from one catenary voltage to another, involving the following sequence: main switch off – pantograph down – selection of system-change submenu on the display – selection of new voltage system. Once the new system had been chosen in this way, it was still necessary to raise the pantograph and to turn the main switch on again.

This whole procedure took about 60 seconds and, while it was going on, drivers also had to keep their eyes on the track ahead and watch what the CCD (command control display) was doing. Figure 5 shows the individual areas on which the drivers' eyes came to rest during the system-change procedure, while Fig. 6, by way of contrast, shows the distribution of the points of eye contact throughout the whole of the test run.

Despite the fact that the drivers had to pay more attention to the TDD (technical and diagnostic display) during this time, they gave a very positive rating for the way the voltage change had been arranged on the TDD. They found that the menu structure, in particular, facilitated system changes and that there were no mistakes made in operating it. The completed questionnaires revealed that the procedure implemented on the Prima II was simpler and more practical than other systems.

5.4 Looking for information on displays

The analyses of the drivers' eye movements showed that, while driving, they paid a lot of attention to the CCD in general, especially to the speed indicator and the ETCS elements (diagrams, pictograms and text messages) and the status messages. There were very noticeable differences in the amount of attention paid to the CCD between operations with trackside signals and those under ETCS control (with cab signalling). In the former case, drivers spent a mean 26.0% of their total time looking at the CCD, 40.5% looking at the track ahead and 14.1% looking at the electronic timetable sheet. In the latter case (with ETCS), the time spent observing the CCD rose to 39.4%, that spent looking at the track ahead fell to 36.3%, and just 8.5% was still left for the electronic timetable.

In overall terms, the eye-tracking measurements confirmed that the displays had been ergonomically favourably designed.

6 Life-cycle costs (LCCs)

In order to assess whether a large-scale introduction would also be economically viable, the probable life-cycle costs of the EUDD*plus* concept for a driver's desk were estimated. This study took the market-penetration scenarios already produced during the EUDD project as one of its inputs and applied the same LCC calculation tool as had already been used for the MODTRAIN project. The results suggested possible LCC savings of 12% compared with conventional desks, working on the assumption of a batch of some 70-90 EUDD*plus* desks with a modular structure and without any significant modifications in the engineering and manufacturing process to tailor them to meet the specific requirements of individual customers. If it were to be possible to manufacture larger batches, then the LCC savings potential would be greater. It is expected that the maximum possible savings compared with conventional driver's desks would be around 30%.

7 Conformity with TSI requirements

A comprehensive appraisal of conformity was performed by taking the EUDD*plus* specifications laid down in UIC Leaflet 612-0, on the one hand, and the desk built into the test locomotive, on the other hand, which was found to satisfy the EUDD*plus* specifications to a rate of 80%.
The yardstick used for the conformity appraisal was comprised of the "essential requirements" of safety, reliability, availability, health, environmental protection and technical compatibility as defined in detail in the "recast" interoperability directive 2008/57/EC [2] and also in the future Technical Specification for the Interoperability (TSI) of "Locomotives and Passenger Rolling Stock" for the conventional railway system (TSI CR LOC&PAS RST) [3]. These requirements are presented in a comprehensive set of parameters in Annex VII to the above-mentioned interoperability directive and in the corresponding accompanying technical documents.

For the purpose of the conformity assessment, the parameters selected were those that are relevant for appraising the train driver's place of work, such as brake functions, visual and audible vehicle identification, internal design of the cab, working conditions, arrangement of the human/machine interface, markings on the desk and equipment. Taken in combination with the corresponding text passages of the TSIs, there were found to be more than fifty relevant assessment criteria.

The evaluation of the EUDD*plus* specifications was done in practice by comparing them with the corresponding passages in the TSIs and UIC Leaflet 612-0. The appraisal of the test cab as implemented in the Prima II locomotive was based on visual inspections and the statements by the drivers and Alstom's technical experts.

The outcome of the assessment of conformity produced the following picture. On the grounds of those assessment criteria that were actually considered, the EUDD *plus* specification scored a conformity of 86%, whereas the test desk as built was found to meet 79% of the requirements in the future TSI CR LOC&PAS RST.

8 Results and prospects

EUDD*plus* marks the end of a period of nearly twelve years of intensive pre-competitive research and development work, which has resulted in major progress towards a standardised European driver's desk with a harmonious functional arrangement and satisfying fundamental ergonomic principles.

This led the UIC and UNIFE in June 2010 to publish a joint "Technical Recommendation for Driver Machine Interfaces in the scope of TSI High Speed and Conventional Rail", based on UIC Leaflet 612-0 and the results of the MODTRAIN/EUCAB and EUDD*plus* projects [4].

The results of the EUDD*plus* project are also having a very considerable impact on the activities of the competent working body, CEN/TC 256/WG 37, at the European Committee for Standardisation (CEN). It is intended to produce a new European standard, which, in consideration of the dimensions of drivers' bodies, is to define general design rules for the access to driver's cabs, the field of vision looking forwards, including the positioning of any signals needing to be considered, as well as the assessment procedure for the TSI requirements as regards the basic layout and accessibility of equipment and operating elements.

References

[1] UIC 612-0 Driver Machine Interfaces for EMUs, DMUs, locomotives and driving coaches – Functional and system requirements associated with harmonised Driver Machine Interfaces, first edition, June 2009

[2] Directive 2008/57/EC of the European Parliament and of the Council of 17 June 2008 on the interoperability of the rail system within the Community (Recast)

[3] ERA Interoperability Unit: Trans-European Conventional Rail System – Subsystem Rolling Stock TSI "Locomotives and Passenger Rolling Stock"; version 3.0 – final draft, 03 August 2009

[4] UNIFE/UIC: Technical Recommendation N°100_002 Driver Machine Interfaces in the scope of TSI High Speed and Conventional Rail; 07 June 2010