Usability testing of the future standardized European Driver’s Desk under “real world” conditions

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In order to increase the competitiveness of the rail transport sector in Europe, a standardised and harmonised driver’s desk for locomotives was developed. In order to evaluate the functional arrangement, the handling and the layout of the proposed desk, manufacturers, railway operators, research institutes, relevant associations and standardisation bodies were brought together within the EUDD*plus* project. The core activity of the project was a 4-week long testing phase using an Alstom Prima II locomotive fitted with a standardised drivers desk. The tests were conducted at the Test and Validation Center Wegberg-Wildenrath in Germany and involved drivers from 10 European countries.

1. Interdisciplinary and international approach

The idea of a standardised driver’s desk for railway engines should help reducing (organisational) barriers still existing for cross-border rail traffic in Europe. Rail passenger traffic is expected to double and rail freight traffic to triple by 2020. Due to different operation regulations and different historical developments, the driver’s desks in use today differ in arrangement, functionality and in operation philosophy. About 10 years ago, the European Commission decided to initiate and finance a program tasked with the conception of a new harmonised driver’s desk for locomotives and multiple units. With its interdisciplinary and international approach aimed at involving all relevant railway stake holders, the project EUDD, for “European Driver’s Desk”, developed standards for the new concept, placing emphasis on improved ergonomics and modularisation. The results were tested in virtual reality, taking into account the latest research in ergonomics (Rentzsch et al. 2006). In 2003, a prototype based on the corresponding Industrial Design Mock-Up has been constructed, with the following aims in mind:

- reduction of hardware control elements by integrating their function in multi-function-displays
- enhanced functional modularisation of the remaining controls on the desk
- improvement of the driver’s safety

The prototype, tested by 40 drivers from 7 European countries, received a very positive feedback from both experts and drivers. It later served as mock up for the EUCAB functional verification, which was part of of the Integrated Project MODTRAIN. As the first tangible and testable result, the MODTRAIN/EUCAB mock-up provided refinements of the specifications before the testing session on the functional prototype and on the SIMUFER simulator in Lille 2006 (Rentzsch, Miglianico & Georget, 2008). The outcome was written up in the UIC 612 leaflet.
The objective of the EUDDplus project was to integrate a driver’s desk according to the UIC leaflet into the Alstom PRIMA II locomotive platform and to test it under “real life” conditions. The field tests performed in November/December 2009 at the Siemens Test and Validation center Wegberg-Wildenrath (Germany) aimed at proving the harmonised driver’s desk's benefits in terms of ergonomics and operability. All in all 17 drivers from 10 European countries took part in the field tests. Their assessments were collected and summarised to improve the UIC leaflet, so that it could be used for Europe-wide standardisation. Figure 1 shows the EUDD*plus* driver’s desk of the PRIMA II.

Figure 1: Standardized driver's desk as described in the UIC 612 leaflets (state on Oct.08)

2. Methodology

2.1 Design of the test scenarios

In order to cover the most important situations occurring during normal operation, six scenarios were formulated and imposed on the drivers. The first one, designated Scenario 0, was intended to familiarize the driver with the new desk layout, the track and its environment. Scenario 1 repeated Scenario 0 under daylight conditions and Scenario 2 under night conditions. The configuration of the train for scenarios 0-2 consisted of the 19.5 m long locomotive pulling 12 load wagons for a total weight of 275t. The wagons were used to simulate realistic acceleration and braking curves to the driver. The maximal allowed speed of 120 km/h on the largest test ring of the test centre made it possible to execute acceleration and slowdown sequences in a satisfying range of speeds. The first three scenarios included the simulation of cross-border operations with change of both power supply and protection systems (ETCS levels), and routine sequences like pre-departure tests, stopping at a red signal, and neutral sections. They were conducted during the afternoon of the first test day.
On the second day each driver began with two scenarios which included incidents and degraded situations like emergency braking, driving in standing position, failure of a display or damage to vital systems or equipment of the locomotive (scenarios 3 and 4). Scenario 5, the final scenario, consisted of executing shunting movements on a special test track including a slope of up to 40 per mil.

Before beginning the test with the real locomotive the drivers could familiarize themselves with the new desk layout on a simulator provided by Alstom. The time at the simulator was also used to give instructions about the test, including the information about scenarios, data collection, the time table and the test tracks.

2.2 Hardware and software evaluation

The tests were intended to verify the improved handling of the controls and examine the interaction between the driver and the displays. The evaluation of the hardware was focused on proving strain reduction for the drivers achieved through the design and positioning of the controls on the desk. The special design of the driver's desk, based on recommendations of the UIC 612 leaflets, contains e.g. modularisation of the controls on the driver's desk (Figure 2): The controls which are often consecutively used or whose functions are related to a common factor are grouped in one module. Thus, an energy set of controls on the left side of the desk gathers the Main Circuit Breaker, Pantograph and Train Power Supply switches. Next to it are the modules for the ATP system (ETCS controls) and the door control. Both consist of three switches.

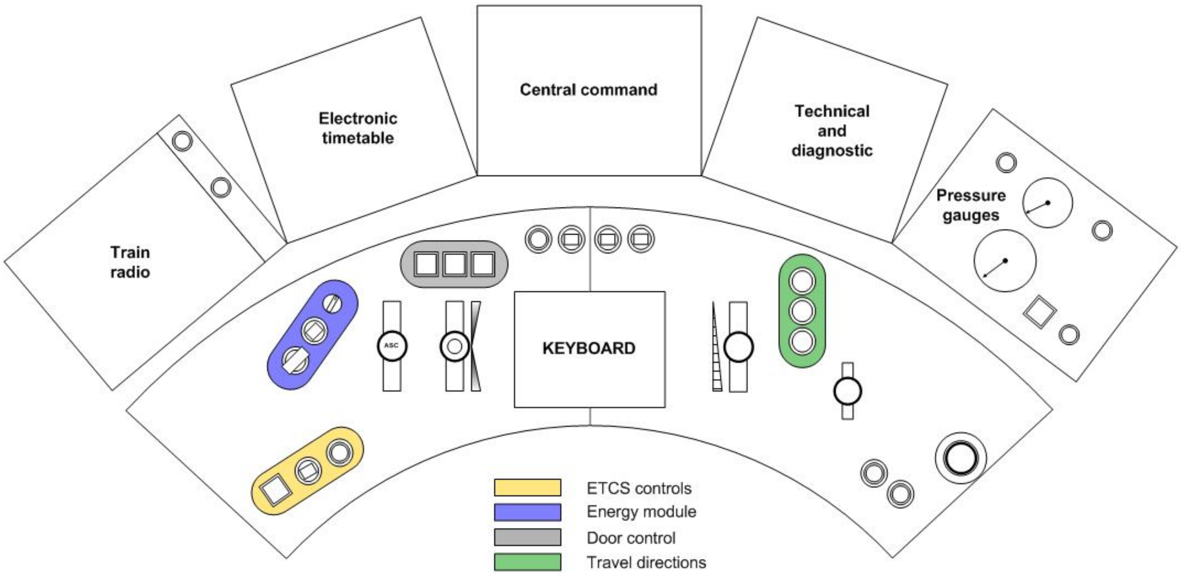

Figure 2: Modular grouping on the driver's desk

The on-board display system, composed of four standardised screen units, should keep stress levels of the driver as low as possible. The flexibility of these interfaces, in which a great range of functions are integrated, is expected to solve recurrent problems of interoperability in Europe. Namely the implementation of different national ATP systems and languages in the Driver's Display System will improve the operation on network crossing lines. Additional to the advantages gained by using LCD screens to display the needed information, it also eliminates the risks inherent in displaying too many functions and information within the small space of one screen unit. To prove this, it was one task of the ergonomic evaluation to establish if the density of information on the screen units is appropriate. The tests were also used to determine the usability in regard to monitoring of information and navigation on the displays. Special attention was paid to check if the used pictograms are self explanatory and logical for the user.

2.3 Human factors methods

During the mentioned test scenarios, various data was collected by the ergonomic team to get a holistic view about how the drivers evaluate the driver's desk. These included:

a) Self-reported methods: Questionnaires, a rating scale for stress and strain and data from a half-structured interview. By means of the used questionnaires, the test drivers assessed the reachability, the perceptibility and the operability of the controls on the desk as well as the readability, the understandability and the usability of the software elements.
b) Measurements: Registration of the test driver's eye movements and measurements of luminance and contrast in the driver's cab. The chosen eye tracking system consisted of a head mounted optics with a scene camera, providing the train driver with total freedom of movement while driving.
c) Registration of all operations at the driver's desk by a data recording unit (DRU). In connection with the eye movement recordings it was possible to derive objective data about the usability of the desk from this data.

2.4 Reference tests

In order to validate these methods for the data collection and to test the designed scenarios, reference tests were performed several months before the main testing session on two locomotive platforms, the Bombardier Talent of the Austrian railways and the Skoda 109E. The first test on the Bombardier Talent involved one driver whose eye movements were recorded during a scheduled local train run. The tests demonstrated that it is possible to use the eye tracking measurement equipment without distracting and disturbing the driver. They also proved the feasibility of deriving objective data from the gained measurements. The recordings revealed the elements which are monitored by the driver often or for a long time while driving. The data is also used to establish the baseline behaviour of the driver while using a known desk layout. Through comparison of the data with the measurements at the new desk layout it is possible to establish the improvements gained with the standardised desk.

The Skoda 109E engine was used as platform for the second reference test. During the two-day-length session four drivers from the Czech Republic, Germany and Hungary drove the latest locomotive from Skoda, whose design took the earlier version of UIC 612 leaflet into account. The test took place at the Velim test centre in the Czech Republic. The design of the questionnaires and scenarios for the main test was developed based on the experiences of this reference test. Furthermore, like the tests in Austria, the results of the reference test in the Czech Republic were used to determine the advantages of the EUDD*plus* driver's desk compared to others.

3. Results

3.1 Hardware: modular arrangement of the controls

After the completion of each scenario the drivers were asked to assess the desk and the cab in general on a scale from 1 to 4 in regard to the experienced quality, comfort, beauty and usability. The results of these general questions are summarized in Figure 3 and are very positive.

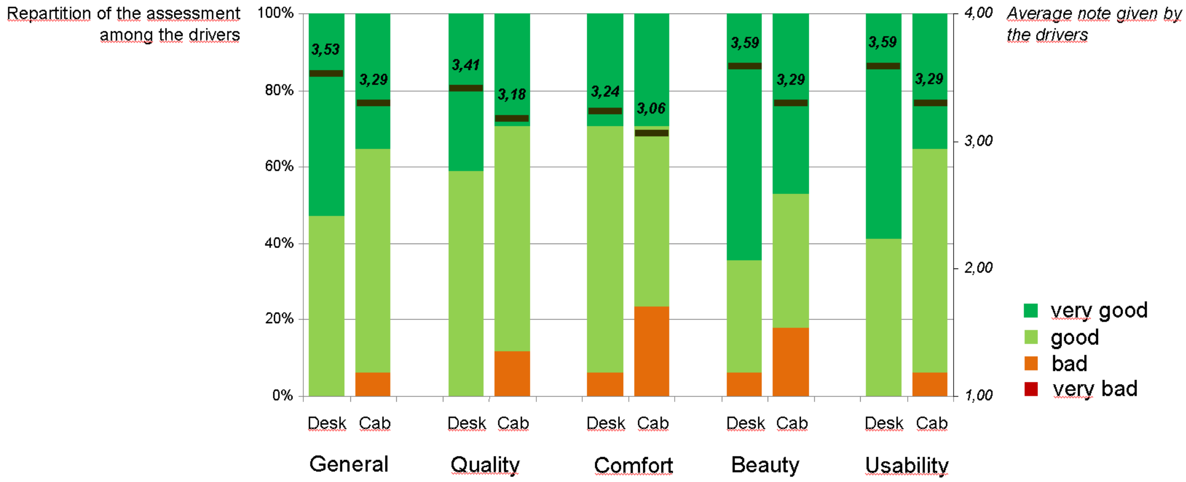

Figure 3: General assessment of the driver's desk and the whole cab

The drivers appreciated the proposed desk, particularly its beauty and usability. The metallic blue colour of the horizontal surface and the bright grey of the vertical instrumentation board was described as very pleasant for the eyes. The comfort in the cab received the worst feedback, e.g. because of the seats uncomfortability and difficulties in adjusting the seat in height and depth. The very positive assessment of the desk's usability proves that the drivers particularly appreciated the modular structure of the arrangement of controls on the driver's desk. Due to the human information processing the modularisation and grouping of elements improves the familiarisation with the new interfaces. These subjective results from the interviews and questionnaires were confirmed by the measurements of eye movement. The drivers were able to recognise, reach and operate all of the controls easily, even during first use. The search and operation time for any given control element during first time usage was not significantly higher than during second and third time usage.
The conclusions of the tests led to some minor changes regarding the location of the controls, like moving some elements to prevent access to them being blocked by other elements. With the realisation of these changes, the new arrangement will allow even more intuitive handling. The necessary changes especially concern two groups of controls, namely the door control and energy modules

(grey and blue areas in the Figure 2). The drivers reported that the reachability of these elements is too low due to the placement of two levers in front of them. Furthermore, as already mentioned before that one of the basic goals of EUDD was the *reduction of hardware control elements* on the desk, and particularly in the driver's field of view. Thus, elements which are not relevant for driving, e.g. air-conditioning and lighting, are placed on two panels below the desk and on the rear wall of the cab. While the driver strongly appreciated the groupings below the desk, a consensus emerged against the placement of some control elements, e.g. the holding brake, on the rear wall panel. It was stated that the red and green push buttons used for the engagement or release of the corresponding brakes in stand-still must be clearly visible at every moment of driving. Furthermore, every alert button is important in case of an emergency and, consequently, must be placed on the vertical instrumentation board at eye level.

3.2 Hardware: some functions still need adjustment

Despite the overall positive evaluation, some special problems were reported with the operation of a few hardware control elements on the desk, e. g. the Traction/Brake Controller, the Pantograph Control and the Driver Activity Control (DAC). The function “Pantograph emergency”, which is integrated into the pantograph control at its end position, can be easily activated by accident. To avoid this, the effort needed to push the pantograph lever into its last position should be higher than on the test engine. It was also highlighted that the Traction/Brake Controller has the same problem regarding the zero position.

Regarding the remarks of the DAC used on the PRIMA II (implemented in three different ways, as recommended by the UIC 612 leaflet: as a sensitive button on the top of the Traction/Brake Controller, as sensitive buttons on the side of the desk and as a foot switch) the drivers generally approved of the placement of a DAC control on the top of the Traction/Brake Controller. They only criticized its implementation as a sensitive button, because it is too difficult to use while driving.

The shape of the desk elements was assessed very well, due to the fact that almost all controls have a unique shape. Only a few changes were proposed, e. g. concerning the equal shapes of three controls for different functions in the centre module. One further improvement was suggested by the drivers regarding the recognisability of the different elements in a darkened cab. Self illuminating or background lit markings would help to find the controls in the dark. Without the illumination some drivers failed to distinguish the elements during operation in darkness.

3.3 Software

According to the chosen configuration of the interfaces, the timetable is displayed on the left side of the instrumentation board, speed and ETCS information on the centre, diagnostic and technical data on the right side. The drivers appreciated this shift of the driving functions to the displays. This lead to an increased focus on that source of information compared to the two layouts used in the reference tests. The engine drivers used almost 60 % of the overall driving time to monitor the information provided on the display system.
The eye tracking recordings also demonstrated that with the European Train Control System (ETCS) the drivers eyes fixed the following elements according to the following distribution, given in percentages of the total time of the recording:
- 31.3 %: speedometer
- 8.5 %: voltage, current, traction and pressure bars
- 6.6 %: core of the timetable

These figures lead to the conclusion that these elements should be positioned in the driver’s direct field of view and should be easily perceivable and understandable.

3.4 Design of the electronic timetable (ETD)

It was anticipated and proven by the eye tracking measurement that, due to the driving environment created for the tests and the adoption to an unfamiliar desk, the drivers will need more time to search

for the necessary information on the displays compared to using a familiar desk. This was particularly the case during some of the sequences of the 6 scenarios.
By isolating the concerned sequences, problems due to low readability of characters and other difficulties concerning the understandability of instructions could be identified. The most serious problems concerned the indication of position, speed and time shown in the timetable. The font used was assessed as too small by 53 % of the drivers. The measured sizes, when compared with human factors standards (Schmidtke, 1989), are confirmed as not acceptable at the driver's workplace. The design of a standardized electronic timetable seems rather complex because of the variety of driving philosophies and strategies used in Europe. While some drivers are considering it to be a simple itinerary sheet, similar to the well-tried but outdated printed version, other drivers are perceiving it to be a driving tool to be taken into account, part of the trend to an ever more assisted driving.

EC 191

191		Vmax = 140 km/h Bhmax = 140 %		
arrival	departure	km/h	km	description
00:00	00:02	**60**	**0,0**	**Schwarzach-St. Veit**
		70	**0,7**	
	00:05		2,2	Abzw Swa 1T
	00:08		5,7	**Loifarn**
		80	**7,7**	
	00:11		9,3	Abzw Lof 1
		90	**9,5**	
		130	**10,8**	
			11,8	Sbl Lof 2
	00:14		14,3	**Dorfgastein**
			15,7	Schutzstrecke
			17,2	Indusi 1000 Hz
		90	**18,2**	
00:17	00:18		19,3	**Bad Hofgastein**
			21,8	Indusi 1000 Hz
			22,4	Bad Hofgastein Haltestelle
	00:21	**70**	**22,6**	Abzw Hg 1
	00:24		25,4	**Angertal**

Figure 4: Example of printed timetable

The ETD got the worst assessment in comparison to the other two displays. The high amount of information, illogical position of functions on the display and the poor visibility of information were the most severely criticized points. Additionally, the highlighting caused some irritation: The display highlighted the next position on the timetable and not the current one as expected by most of the drivers. The fact that many test drivers were confronted with problems of perception and/or understanding of the timetable demonstrates that a redesign of the information presentation is necessary. A user-friendly display of these elements should reduce the time needed to search for information on the screen and consequently reduce the distraction from monitoring the track.

3.5 Importance of the central display

Due to the problems with the timetable presentation the time spent on the recognition of the information provided on the ETD is very high. But it is still smaller compared to the time spent on supervising the Central and Command Display (CCD): while the drivers fixated the ETD averagely 60 times in 10 minutes, the CCD was fixed 275 times in 10 minutes. Taking into consideration that a fixation means the monitoring of a display longer than 200ms, the cumulated time for 275 fixations is about 4 minutes. In contrast to the ETD, where the very high fixation rate is an indicator of poor design, the frequent monitoring of the CCD is a result of the importance of the information presented there for driving (especially under ETCS supervision). Hence, the CCD should display only information necessary for driving. This information must be designed and placed on the screen in ways that supports the recorded number of short visits.

The most impressive results with eye movement registration were obtained when the durations of all measured braking sequences during all the scenarios and while driving under ETCS supervision, are isolated and accumulated. As assistance for braking, the ETCS displays a curved bar around the speedometer on the CCD, decreasing in accordance with the braking curve, as well as a vertical bar on the left side of the speedometer indicating the remaining braking distance. This layout makes it necessary to monitor the CCD during all the braking sequences: the drivers mainly fixed the speedometer and the track during the on average 42 seconds long sequences.

The basic CCD image on the PRIMA II was assessed very positively in general. The information for driving under ETCS is very well implemented. The only negative remarks were given about the braking curve which is displayed without any announcement. The value of the braking distance was assessed as too small and should decrease in a way that it is more easily followed by the driver. Additionally, some pictograms were not self explanatory, e.g. the abbreviation CTP.

It is essential for the study to recognize that an average of 74.5 % of the gaze transitions are between the central display and the other elements on the desk. This value fluctuated between about 60 % (when only the time of the power supply transition sequences are considered) und up to 91 % for the accumulated time during braking sequences. During ETCS supervision the gazes returned to the CCD from all the other controls of the desk, leading to a star topology of the gaze transitions which seems to be typical for the EUDDplus driver's desk (Figure 5).

Figure 5: Star topology of the gaze transitions during breaking sequence while driving with ETCS (average of all breaking sequences)

The amount of gaze transitions from other controls/displays to the central display is reduced to 55.4% without ETCS supervision. Without the information from ETCS the CCD displays only a speedometer comparable to a common mechanical speed indicator and the drivers shifted their attention to the following three areas:

- the electronic timetable was monitored 42 % longer without ETCS supervision during the whole time of measurement
- the track: 32 % longer
- the technical display: 26 % longer

Without ETCS data on the CCD, with which not all test drivers were familiar, engine drivers relied more on their experience and therefore spend more time looking to trackside signals for guidance. The shift of attention towards the track is more evident during acceleration and braking: During the last hundred meters of braking without ETCS the drivers constantly fixed the track and tried to determine a point on the track where they wanted to stop.

Since, as shown above, the driving strategy under ETCS supervision switches from track monitoring towards additionally displayed information on the CCD, it is necessary to provide a user-friendly design especially for ETCS information presentation and CCD design.

3.6 Technical and diagnostic display (TDD)

The displayed technical data on the TDD was not observed as often as the data on the CCD. The average duration of a TDD fixation was about 25% shorter than the average fixation on the CCD. The drivers only monitored parameters if deviations from the normal situation occurred. During normal driving situations the TDD was only given short glances to quickly obtain information about the technical condition of the systems. To support this driving strategy of short glances, the technical information on the UIC 612 (EUDD*plus*) compliant TDD – the voltage in kV, amperage in A, traction in kN, brake cylinders pressure and brake pipe pressure in bar – should be placed accordingly on the screen. For this reason the focus of the evaluation was placed on the shape, colour and arrangement of the pictograms.

The best sequence for a detailed study of perception of provided information is the sequence of power supply transition. This sequence is interesting as the amount of interaction with the TDD is higher than during other sequences (like braking, acceleration, stopping…). Thus, during the power supply transition, the technical display is observed a total of 27.9 % of the reception duration, marginally higher than the central display (27.2 %).

Figure 6: Density distribution and percentage values of the reception duration during an average power supply transition

Due to the quantity and importance of the technical information displayed on the TDD, an appropriate positioning of the data results in a strategic reduction of searching time.

The TDD main screen layout got a good assessment in general: The presented information is well located and proportioned. Minor improvements were proposed concerning the pictogram for the DAC alarm as it is disadvantageously positioned in the right corner of the TDD. It is difficult for the driver to perceive it instantly while monitoring the track and the speed on the CCD. Additionally, the text messages used to signal any failures (e.g. failure of the pantograph) should be bigger and put in bold to gain the attention of the driver more quickly.

Some improvements were also suggested regarding the placement of information on the TDD: On the test engine the main pipe pressure could only be found in a sub-menu of the TDD. All drivers agreed that this information must be displayed on the main screen as it is important for the easy and quick recognition of problems within the pneumatic system.

The test persons also remarked that there is no possibility for manual adjustment of the displays background lighting and contrast. An installed automatic brightness adjustment could not handle all illumination situations properly, since each driver has different preferences.

4. Outlook

The results demonstrate that the proposed standardization of the driver's desk in UIC 612 for European countries is well received by end users. They generally assess the layout and the operation positively. The tested driver's desk increases the possibility of intuitive and time-effective operation. Changes put forward by the test results should be taken into account by creating an further improved version of the UIC 612 leaflets.

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