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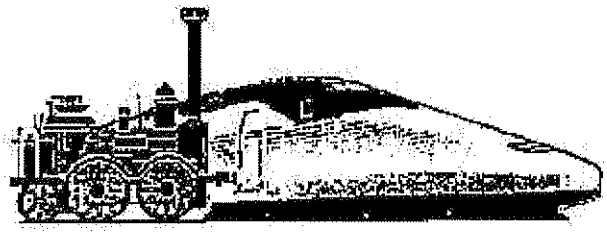

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HUMAN FACTORS EVALUATION OF A STANDARDIZED DRIVERS DESK UNDER "REAL LIFE" CONDITIONS

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Christina KARSTEN[2], Manfred RENTZSCH[2]

Summary: With Europe growing together it is necessary to ease cross-border rail traffic in order to improve its economics and efficiency. The EU-funded projects EUDD and MODTRAIN/ EUCAB were initiated in 2001 to developing a standardized and modularized driver's desk, with the target to reduce existing technical and operational barriers which still hamper network crossing rail traffic. Based on the results of EUDD and its adjustment within the simulator tests of MODTRAIN/EUCAB, EUDDplus aimed at determining the economic and ergonomic benefits of the interoperable and harmonised train driver's desk compared to existing ones. The results of evaluation will be used as a further step towards a unified European driver's desk.

1. Introduction

Due to different operational regulations and historical developments of the rail operating companies in Europe, the driver's desks in use today differ in arrangement, functionality and operation philosophy. Next to higher development costs of new rolling stock and consequently higher training costs it is also a safety issue to operate locomotives with different desk layouts.

As rail passenger traffic is expected to double and the rail freight traffic to triple by 2020 it is necessary to improve the rail operation to strengthen the competitiveness of the rail transport sector compared to other modes of transport. One such possibility is a harmonised driver's desk for application throughout Europe.

Based on the outcome of the EC financed Projects EUDD (**E**uropean **D**rivers **D**esk) and MODTRAIN the UIC 612 leaflet concerning the "Driver Machine Interfaces for EMU/DMU, locomotives and driving coaches" was developed with emphasis on improved ergonomics and modularisation. (Rentzsch et al. 2006).

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After the testing phase of the new concept in virtual reality within EU-CAB (Rentzsch, Miglianico & Georget 2009), a locomotive platform was equipped with a driver's desk compliant to the UIC leaflet. The EUDDplus project aimed to test and evaluate the new concept under "real world" conditions.

The new multisystem-capable locomotive PRIMA II (25 kV AC, 15 kV AC, 1.500 V DC and 3.000 V DC) from Alstom was chosen as test platform for the integration of the driver's desk.

Fig. 1: Alstom PRIMA II locomotive and its driver's desk

2. Modularization in the EUDDplus Driver's Desk

The main aspect of the innovative design of the driver's desk is the modular grouping of the control elements on the desk: The controls which are often consecutively used or whose functions are related to a common factor are grouped into one module. It intends to provide an intuitive and quick operation. Following segmentation was used on the PRIMA II:

- On the left side of the desk four modules can be found: the ETCS module, the energy set of controls (Main Circuit Breaker, Pantograph, and Train Power Supply). Next to it, also grouped, are the three push buttons for the door controls. The controls for Traction/Brake and Automatic Speed are also positioned on that side of the desk.
- The following switches are located in the central module: Sanding, External lighting, Task and Driver's Cab Lighting, Release Brake
- On the right side of the desk the Automatic, the Emergency and Direct Brakes are located, as well as the three buttons for the selection of the direction of travel and the external warning horn.

On the left side under the desk the controls for the climate control can be found. The right module under the desk includes the functions for windscreen (wiper, washer, heating..). Foot switches for DAC (driver activity control), the horn and adjustment of the foot rest are located in the foot space under the desk.

The on-board display system contains four standardised screen units, from the left to the right side: the Train Radio Display (TRD), the Electronic Timetable Display (ETD), the Command Control Display (CCD), and the Technical and Diagnostic Display (TDD). 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 segmentation of the functions between four displays and the flexibility of these interfaces are used to reduce the number of hardware elements on the desk and to provide the possibility to operate it in different countries with different languages and train protection systems.

3. Methodology

3.1. Test design

The tests took place at the Siemens Test and Validation centre Wegberg-Wildenrath (Germany), which provided the possibility to design reproducible driving situations and to simulate as many interactions with the driver's desk as possible, during November - December 2009.

Each test driver accomplished six "real world" scenarios in two test days after a training session on a simulator. The first day was used for three scenarios simulating normal operation in different light conditions (daylight and nightlight) including the cross-border operations with the change of power supply and protection systems (ETCS levels), and routine sequences like pre-departure tests, stopping at a red signal, and neutral sections. In order to provide realistic acceleration and braking curves for the driver the 19.5 m long locomotive pulled 12 wagons with a total weight of 275t. The maximal allowed speed of 120 km/h on the largest test ring of the test centre made it possible to assemble acceleration and slowdown sequences in a satisfying range of speeds. On the second day the test persons run two scenarios with degraded modes and simulated failures, like failure of compressor or the use of the emergency brake due to a simulated problem on the track. The last scenario consisted of shunting movements on a special test track including a slope of up to 40 per mill.

The defined scenarios made it possible to test the use of the desk in a broad range of situations.

3.2. Methods

During the scenarios various data was collected by the ergonomic team to get a holistic view about the opinion of the different drivers towards the new desk layout. The tests aimed at verifying the improved handling of

the controls and examining the interaction of the driver with the displays. The evaluation of the hardware was focussed on the goal to improve the stress/strain sitaution for the drivers through the design and positioning of the controls on the desk.

Subjective Data: By means of the used questionnaires test drivers assessed the reachability, perceptibility and the operability of the controls on the desk as well as the readability, understandability and the usability of the software elements. Self-reported assessments in the form of questionnaires helped to collect high differentiated subjective evaluations. Once aggregated, these data provided a base for quantification of the assessments which are independent of the personal point of view of each driver. By the help of half-structured interviews the assessments from questionnaires could be better interpreted and revealed an insight in the views of the target group who is supposed to use such a desk in the future.

Objective Data: Measurements of luminance in the driver's cab by the system KALIF aimed at providing objective data concerning the contrast situation in the field of view of the driver. In parallel, the eye tracking method was used with a significant number of drivers (11 out of the 17 participants). Its recordings were used to assess the allocation of visual attention on the desk, particularly on the screens. It uncovered insecurities and hesitations of the users' behaviour and, by the combination with the results of questionnaires, helped to analyse the driving strategies. The eye tracking recordings provided essential data for a detailed analysis of the usability of the displays. It was possible to compare these results with results from questionnaires and observations. More than 700 minutes on the Alstom PRIMA II were recorded, during 2 scenarios.

3.3. Reference Tests

Basis of comparison were established thanks to the performance of reference tests on two others locomotives: the Bombardier Talent, series 4024 of the ÖBB and the Škoda 109E.

The Škoda 109E is equipped with a driver's desk based on some specifications emitted by the former project EUDD in 2002. The platform was tested by four drivers on the tracks of the test centre VUZ Velim in Czech Republic at the end of August 2009. The four drivers used scenarios quite similar to those of Wildenrath. The eye movements of two drivers were recorded while driving.

3.4. Test drivers

At least one test driver from each of 10 European countries including big railway operators like DB (Germany), SNCF (France), Trenitalia (Italy),

as well as SZ (Slovenia), ČD (Czech Republic), NS (The Netherlands), SNCB (Belgium), MÁV (Hungary), ÖBB (Austria) and SBB (Switzerland) participated in the field test. A total of 17 drivers assessed the EUDDplus driver's desk.

The same three drivers from DB (Germany), ČD (Czech Republic) and one driver from MÁV (Hungary) also participated in the reference test of Škoda 109E locomotive in Velim.

4. Results

4.1. Results from subjective data

The results demonstrate, that the modularisation as a key idea of the control arrangement on the desk, was very appreciated by the test drivers: compared to the desk of Škoda 109E the element grouping on the desk of PRIMA II is clearly visible.

On the Škoda 109E desk, the repartition of the controls on the desk surface does not always appear logical. Although some functions, often used successively, are located next to each other. The mean values of both assessments are shown in Fig. 2. The modularisation of the PRIMA II desk enhances the opportunity for intuitive handling and reduced the time necessary for familiarisation with the new design. The test persons proposed only changes regarding the position of modules on the desk to enhance the reachability of the functions. Thus, the use of e.g. the Travel Direction buttons is complicated since the module is positioned between two big levers, namely the Automatic Brake and Direct Brake Controllers, and should be moved e.g. to the left side of the desk

Like shown in the Fig. 2 also the shapes of the controls are better assessed on the desk of PRIMA II compared to the Škoda 109E. The reason for that is the unique shape of almost all controls on PRIMA II which provides the possibility of using the controls without looking at them. This kind of operation allows for time to observe the track. The control design of the Škoda 109E offers a range of identical shaped switches and buttons which was confusing for the test drivers and made the use of the correct function difficult.

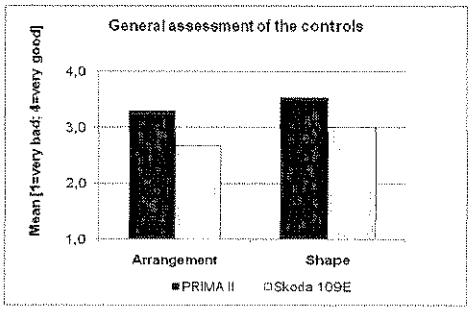
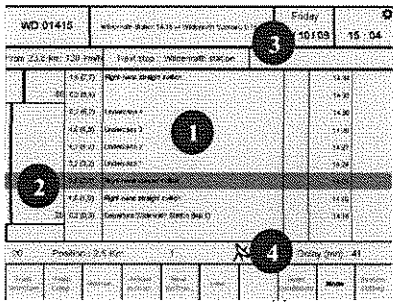


Fig. 2: General assessment of the arrangement and shape of controls on PRIMA II and Škoda 109E

The test drivers appreciated the use of four displays and the modularisation of the driving functions on the CCD display. Concerning the Electronic Timetable Display, the results of the questionnaires confirm the idea that "too much information kills information". As reported by the drivers, the structure of the electronic version of the traditionally printed timetable shall be reviewed and implemented (Fig. 3).



1 - Core of the timetable

2 - Speed restrictions

3 - Train number, time...

4 - Position and delay

Fig. 3: Electronic Timetable Display, as implemented on the locomotive

The presented picture suffers from an unclear structure of the timetable (1), the redundancy of certain data (3 and 4) and globally too small characters. The presentation of the speed (2) was appreciated by the drivers, considering it as a real assistance for the drive.

4.2. Contribution of the collected objective data

Since 2002, luminance ratios in cabs were measured at various locomotives with a video based measurement system called KALIF. The analyses often revealed a too high contrast ratio in the view field of the driver. Spe-

cial attention must be given to the luminance contrast situation between the desk, including the instruments and the outside environment, in order to reduce the stress and strain situation on the driver. This ratios can reach maximum values of 1:60-1:80 on some locomotives. Therefore, the colours of the surfaces on the desk must be chosen in a way to reduce these values.

On the PRIMA II, the horizontal desk is in metallic blue colour and the vertical board in bright grey. The gained contrast ratio was close to 1:20. A value of 1:10 should be considered by the cab designers as an target.

Another area of interest from the human factors point of view for the visual comfort is the direct incidence of light onto the desk and particularly the display units. The measurements during the previous project EUDD demonstrated, that the luminance contrast situation is significantly reduced with an increasing ambient illumination. On the test locomotive glare on the left side of the desk, caused by incident light from the lateral windows, was observed in a few cases.

The eye tracking recordings complemented the subjective analyses of the questionnaires. According to the questionnaires the used characters on the electronic timetable (ETD) were assessed as too small and the structure as too confusing. The measurements of the eye fixations confirmed that the drivers spent too much time reading the content of the timetable. The correlation between the results induced that a new structure of the screen unit should be brought forward which includes a selection and prioritization of the displayed data by the driver.

The eye tracking recordings of the two drivers who tested the Škoda engine proved that they experienced some difficulties in reading the provided instructions to solve a technical failure. The used colours provided not enough contrast between characters and background. Next to that, the test drivers needed to long to search for a certain information in the submenus on the displays. Therefore a redesign was proposed. Due to the different organisation of the menus on the UIC compliant test engine, it was easier and more intentionally for the driver to search for a certain information.

One of the most impressive results of the eye tracking analyses on the PRIMA II is the concentration of the driver's attention on the central screen unit when he is driving with ETCS, as illustrated by the Fig. 4: The drivers fixed the CCD for about 40% of the time and the track was monitored only 36% of the time. This high value demonstrates that further studies are needed to precisely determine which information should be displayed on the CCD while other is only provided on request by the driver.

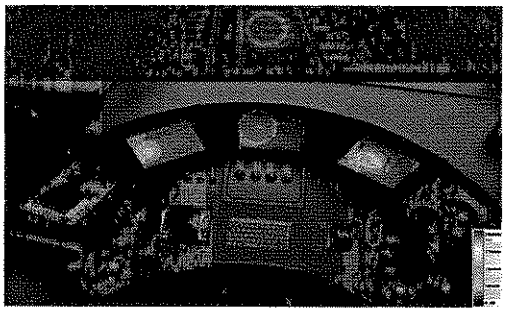


Fig. 4 Density distribution of the average durations of reception on the desk

5. Conclusions

In general the field test demonstrated the ergonomic advantages of the new layout for a harmonised driver machine interface. The test drivers evaluated the arrangement and the layout of the displays as very well. These positive results will help to further promote the proposed design in Europe in order to enhance the economics of new rolling stock and to improve the competitiveness of the rail transport sector compared to other modes of transport.

The latest version of the UIC 612 leaflet, which defines the harmonisation of operational requirements and driver machine interfaces for driver's desk on European rolling stock, will be adjusted in regard to the EUDDplus results. Especially the design of the ETD will be reviewed which will include some new pictograms in order to provide the needed information to the driver in a clear way.

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