Participatory Evaluation and Design of a Subway Train Cabin

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ABSTRACT

This study presents the process of designing a new frontal panel and console for a subway train which included the participation of the train drivers. Firstly, their task and activities were carefully observed. Then, drivers and supervisors were interviewed and a questionnaire was built to get information about the task performance and the importance of the main controls and displays involved on the driving task. Suggestions from the drivers were applied to generate a preliminary project of the console and frontal panel which was validated afterwards by the train drivers.

Keywords

Ergonomics, Participatory Design, Subway System, Conduction Cabin

INTRODUCTION

The history of the Metropolitan 2nd line operation contains serious accidents such as trains crashes, collisions, derailment and disregard of traffic lights. The management argued that these accidents were due to the human error. In relation to the driver, we could verify that the most serious problem includes the cabin environment, where high levels of noise, temperature and vibration were registered. Moreover, maintenance problems associated to the system restrictions cause undesired results such as broken trains and crowded platforms.

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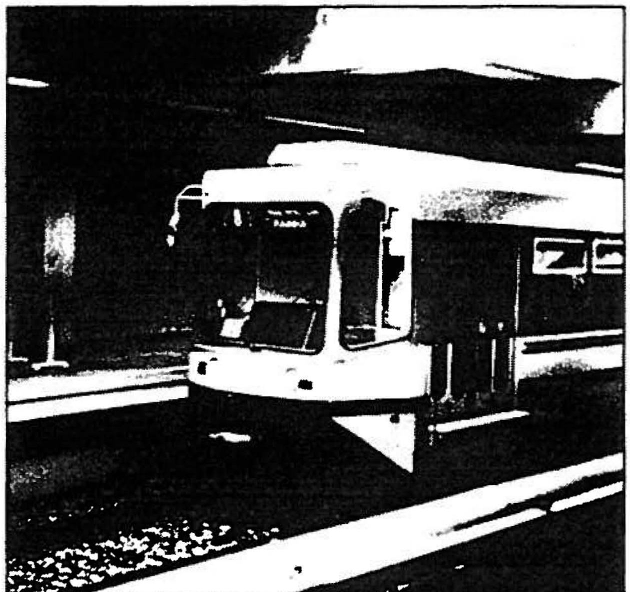

Figure 1: The Subway train of the 2nd Line

THE PROBLEM

While performing the driving task, the driver has to do the utmost to improve the train regularity. A previous ergonomics diagnosis (MORAES et al, 1995) showed that the situation is aggravated not only by maintenance problems but also by environmental and informational problems.

These problems are related to the uptake of information from panels, the manipulation of controls, the communication with the central control system, shunting yard and maintenance. According to the drivers opinions, there are also constraints caused by environmental factors.

As well as being always responsible for moving the train to the next station of the tube, in some cases the driver will be the only responsible for the necessary repairs that can allow the train to reach the next station.

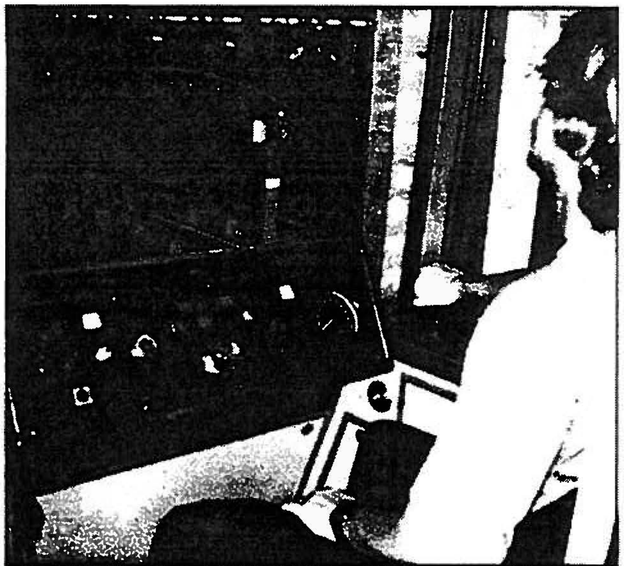

Figure 2: The Subway train cabin environment

METHODS AND TECHNIQUES

Focused interviews with supervisors

Both train inspectors and supervisors were interviewed face-to-face in order to get general information about the train cabin. This information (which included a description of the cabin subsystems, the operation as a whole, signalizing systems, traffic control, passengers, failures and accidents registered) together with the systematic observations, using protocols, were the main support to build the questionnaire which was answered by the drivers.

Questionnaires with drivers to know their opinions and suggestions

The questionnaire was divided into 6 sections:

1. Personal Information:
This section included open and multiple choice questions about sex, age, height, weight and also education levels.

2. Quality of life:
Questions on this part of the questionnaire were about transport and the time spent to get to work, leisure, rest and second jobs or other occupations.

3. Background:
Multiple choice questions related to diseases and visual impairments.

4. Professional information:
This part included questions about occupations, absences and its causes (illness, financial or family problems)

5. General opinions:
On this section the driver was asked to give his opinion about several aspects of the work environment and his mood during his shift and afterwards.

6. Task performance:
This part of the questionnaire was the most specific one, since its objective was to collect information about the main controls, their importance according to the drivers' point of view, concerning the cabin environment, support systems, failures and suggestions to improve the task performance and work conditions.

Before the questionnaire could be applied to the drivers, a preliminary version was tested and evaluated by the supervisors. Some questions were modified, particularly those related to the frequency and to the importance of the controls. These questions were transformed into rating scales to define these levels with more accuracy.

The questionnaire was applied to the drivers as in an interview schedule, that is, drivers were asked the questions face-to-face. This procedure was adopted in order to avoid misunderstandings, doubts generated by the questions and the non-completion of the questionnaire

A total of 33 drivers from the three shifts (morning/ afternoon/ evening) answered the questionnaire during their rest period.

Rating scales to define priorities in the new layout

Some questions of the questionnaire were presented to the drivers using the rating scale technique. These questions were related to the *frequency of activation* of controls and other equipment, the *importance* of the controls and light indicators on the task performance and the *level of disturbance* caused by external agents.

The frequency of activation of controls was defined by the drivers in a 5-level rating scale (frequently, occasionally, seldom, not widely used but extremely important, never) while the importance of controls and light indicators had to be mentioned according to a 4-level rating scale: extremely important, important, less important, not much important.

We also had some opened questions about the task performance, the most frequent failures, the procedures and the tests adopted to solve the failures and suggestions to improve the cabin environment and the safety of the system. These opened questions were used with the drivers in order to let them feel free to express their own opinions.

RESULTS

Before the answers to the questions could be computed, the questions were divided into two groups: open questions and multiple choice questions. The open question results were shown in simplified tables, with the frequency with which they occurred whereas the results of the multiple choice questions were presented using charts.

Analysing the results of the questionnaires we could notice that the most important controls and equipment to the driving task were:

- dead-man lever (100%);
- open/close doors (100%);
- microphone (100%);
- emergency (90%);
- sounder (80% of the drivers defined this command as extremely important).

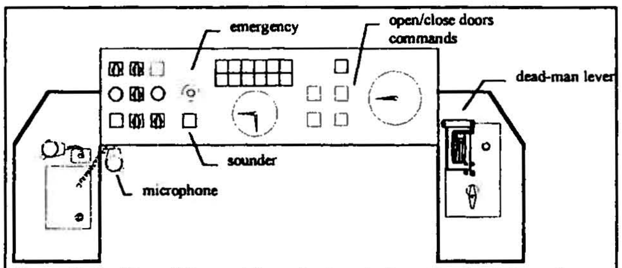

Figure 3: Position of the most important controls on the frontal panel and aside consoles.

In relation to the position and configuration of the main controls, 70% of the drivers considered that they could be easily accessed but their visualisation was reasonable, not so good.

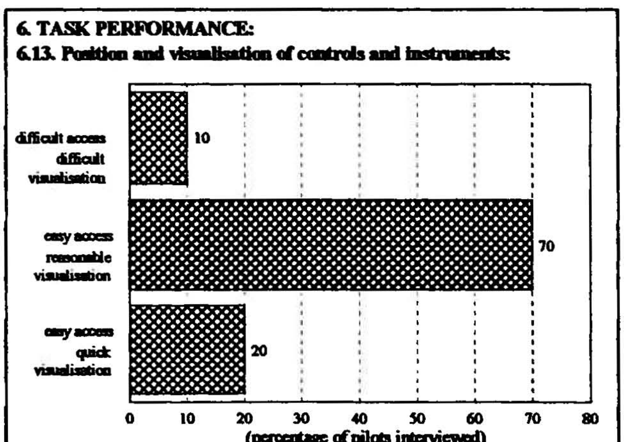

Figure 4: Drivers' evaluation of position and visualisation of the controls.

Although the majority of the drivers mentioned that the controls provided safe manipulation, they complained that their handling was not very comfortable.

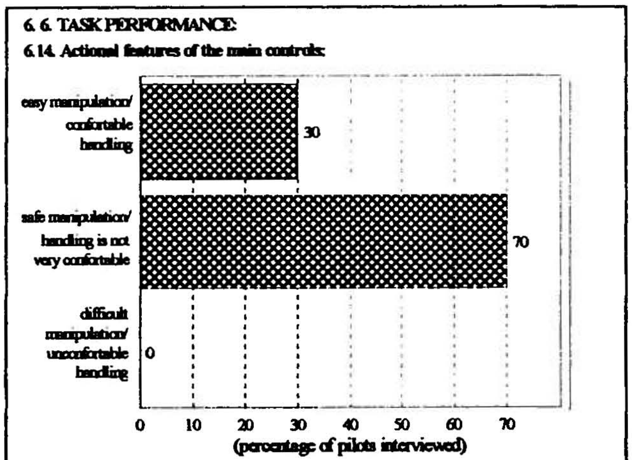

Figure 5: Drivers' evaluation of the features of the main controls

The answers to the questions related to the activation of controls and to the task activities were compared with the systematic observations to check whether the drivers' self-report corresponded exactly to the in-loco systematic observations.

These observation were done in 3 different shifts: morning, afternoon and evening in order to compare the results. During the observations, each researcher registered the uptake of information, the activation of controls and the messages sent and received through THF (High Frequency Telephone) and telephone by each driver.

We can see on figure 6 the frequency of activation of the open/close doors controls according to the questionnaire results. All the drivers answered that these controls were frequently used.

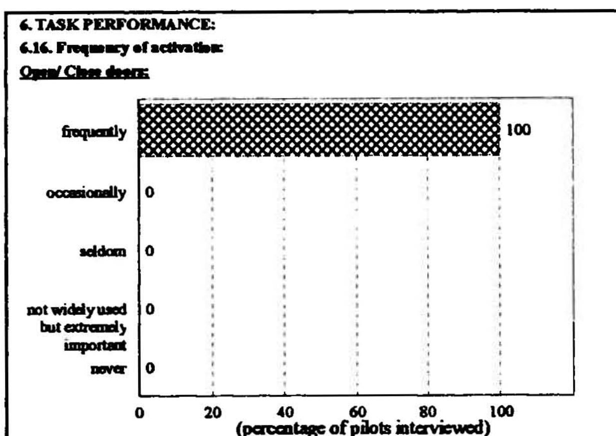

Figure 6: Drivers' report on the activation of the doors command.

When comparing this information with the net based on the systematic observations (Figure 7), which shows the sequence and the frequency of the controls activation, we can verify that the drivers' self report corresponds exactly to their action. The net based on the systematic observations also shows that there is a strong relationship between the doors control and the dead-man lever.

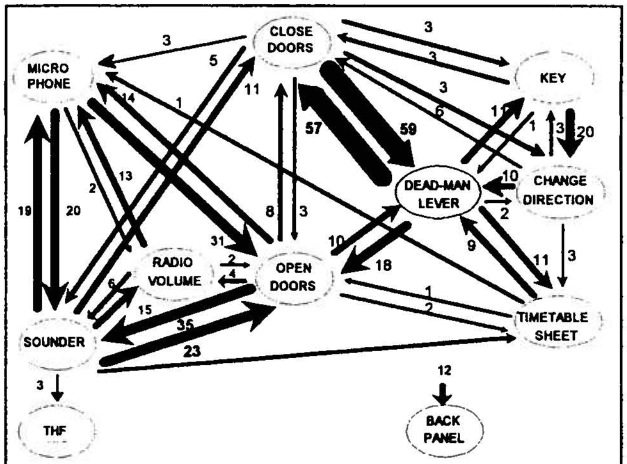

Figure 7: Net based on the sequence diagrams (systematic observations).

On the other hand, the opposite situation may also occur, when the driver self-report does not correspond to his actual activity. The indicators test command, for instance, was mentioned by 90% of the drivers as frequently used (Figure 8), while in the systematic observations, no driver actually used this command (Figure 7). A possible explanation for this case is the difference between prescript task and real task. When answering the questionnaire, the drivers remembered the importance of this control and the instructions received during their training: that it should always be used at the beginning of their driving task, ignoring that they actually did not used this control during the driving the task.

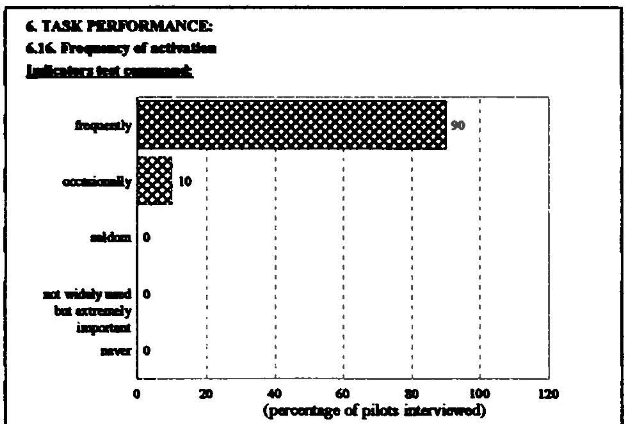

Figure 8: Drivers' report on the activation of indicators test command

The position of the back panel, which includes the main failures indicators, was mentioned as inadequate by 50% of the drivers, emphasising that it should be transferred to the front (Figure 9).

On the current situation, there is only a warning light on the frontal panel which indicates that there is a failure and does not mention which kind of failure is it. Thus, every time this light blinks, the driver has to look at the back panel and try to find the cause of the failure. If the failure panel were transferred to the front, the failures could be immediately identified and corrected by the driver.

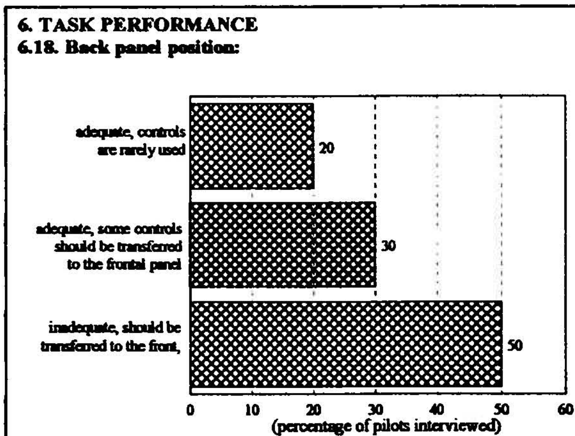

Figure 9: Drivers' opinions about the back panel position.

One of the most frequent complaints of the drivers is about the cabin environment, which was described as uncomfortable by all of them (Figure 10). The most disturbing factors mentioned by the drivers during the interviews were: high temperature, high noise and vibration. Thus, the need of a new project which emphasizes not only the equipment but also the environment becomes evident.

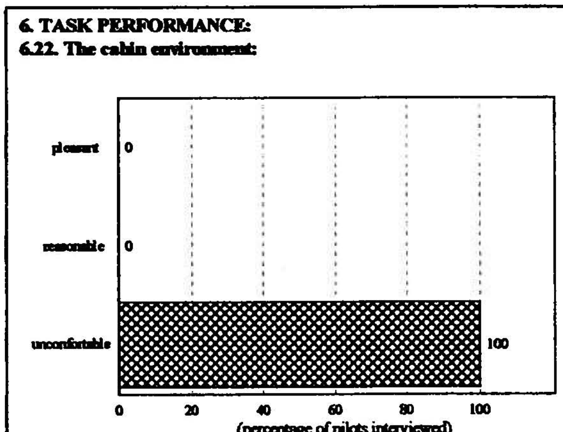

Figure 10: Drivers' opinions about the cabin environment.

SUGGESTIONS FOR THE NEW LAYOUT

In the open questions section of the questionnaire, answers also included suggestions from the drivers to solve some of the problems which were detected on the driver workstation such as those related to the uptake of information, the activation of controls and the communication with the central station, maintenance and shunting yard (see next table).

These suggestions aimed to improve not only the workplace environment but also to increase the safety of the driving task.

Suggestions to improve workplace environment and safety
- improve the maintenance and the availability of spare parts (this is the reason why the drivers have to deal with many failures and there are not trains available to replace the broken ones immediately)
- improve the quality of the rolling stock (the First Line train, for instance, is much better than the train which was being used on the Second Line)
- improve lightning (inside the cabin and inside the tunnels in case the train stops between two stations)
- provide the isolation of the cabin (from both noise and heat - air-conditioned, ventilation)
- install dark windshields to protect from the light of the sun (which most disturbs the drivers in the early morning and late afternoon)
- provide a more comfortable seat (which shall include adjustable parts)
- availability of individual protection equipment (in case it is not possible to isolate the cabin from the external factors - heat and noise)
- improve communication through THF (High Frequency Telephone) or provide an alternative communication channel
- schedule training activities should take place more frequently

The drivers also proposed suggestions related to the dead-man lever, whose evaluation showed that its use is rather problematic and painful. Only 20% of the drivers said that the manipulation of the dead-man lever does not cause discomfort whereas 80% complained about discomfort and pain on the hands and wrists.

6. TASK PERFORMANCE
6.20. Dead-man lever

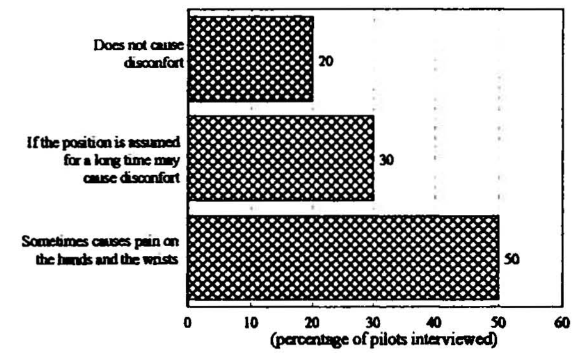

Figure 11: Drivers' opinions about the manipulation of the lever

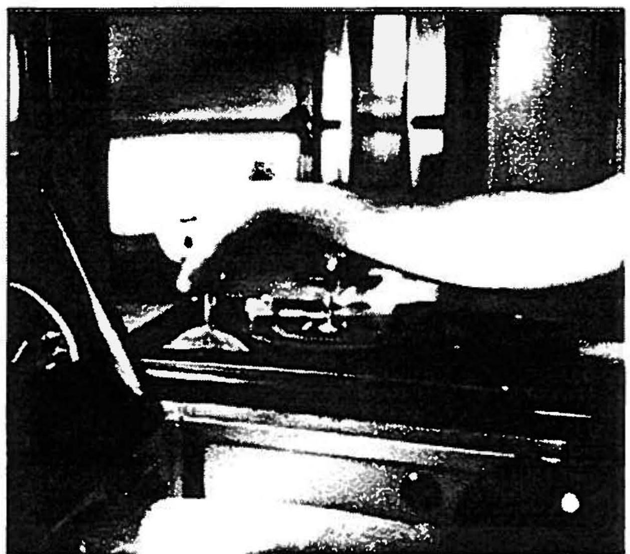

Figure 12: Position assumed while activating the dead-man lever.

Suggestions to improve the dead-man lever
The main suggestion is related to the change of the vertical rotation of the dead-man lever. The driver would contract the wrist to the back (to avoid the activation of the dead-man safety mechanism) and push the lever to the front (to accelerate the train). This suggestion, however, would not eliminate the pains caused by the manipulation of the lever, it would only increase the safety of the system.

New rotation for the dead-man lever

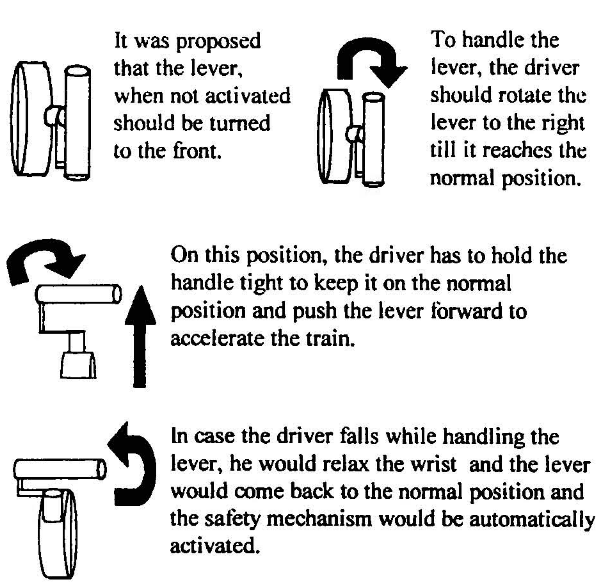

Figure 12: Suggestion to change the rotation of the dead-man lever.

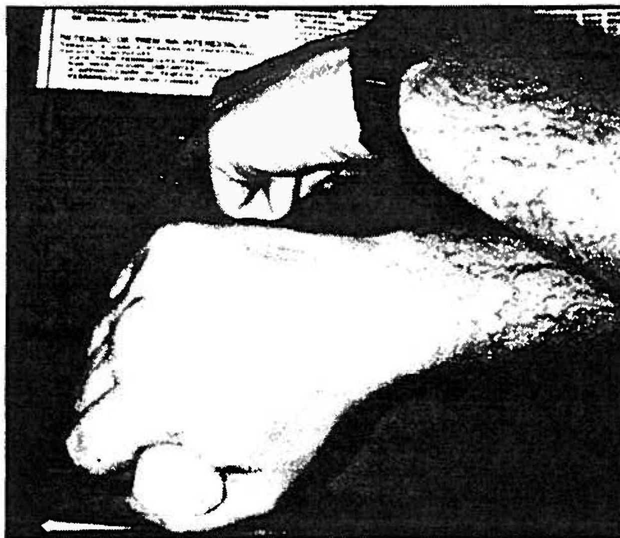

Figure 13: The uncomfortable position assumed while activating the dead-man lever and pressing the emergency button at the same time

This safety mechanism is very widely used by train driving systems and there are several alternatives for the dead-man security mechanism, including those placed on pedals instead of hand levers (HERON & CAVANAUGH, 1989).

The suggestions brought by the drivers do not seem to be adequate to ensure the complete security of the system and to avoid the discomfort of the dead-man lever manipulation during the driving task. Further studies need to be carried out in order to find a better solution.

The activation of the emergency button which is only used on extraordinary situations is also very difficult. As the driver has to operate this button while activating the dead-man lever, he assumes a very uncomfortable position.

Suggestions to improve the emergency button

The button to operate in case of emergency should be joint to the dead-man lever on the extremity of the handle. The driver would be able to press the button while activating the dead-man lever.

The advantage of this suggestion is that if the driver has to get in touch with the PCT (Traffic Control Station) he would have one hand free to do this.

Suggestions to improve the microphone

The first suggestion was to use a different kind of fixed microphone and buttons to choose the function: contact the PCT (Traffic Control Station)/ talk to the passengers.

A disadvantage of this suggestion is that the driver would not be able to talk in the microphone while checking the back panel.

The next suggestion is to use the same movable microphone and add selection buttons on the body of the microphone.

This solution would bring the advantage of allowing the driver to use the microphone wherever he may be on the cabin.

Suggestions to improve the doors controls

Although there were no problems related to the open doors controls, the drivers suggested that the controls were separated in left doors/ right doors (figure 14), instead of open doors/ close doors as they are divided in the current situation.

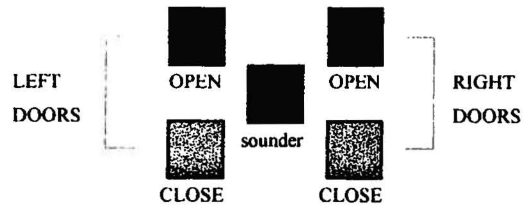

Figure 14: Suggestion to change the doors controls

PRELIMINARY PROJECT

According to the suggestions of the drivers, three alternatives of frontal panel and aside console were generated. The alternatives were evaluated through the link diagram method and validated afterwards by the supervisors and the drivers.

The three alternatives grouped the controls and displays according to their functions The panel was divided into five main groups:

- the first group included the train driving (dead-man lever, commuting button, ignition),

- the second group included doors controls (open, close, sounder),

- the third group included displays related to the train state (warning LEDs, speedometer and manometer),

- the fourth group included light and environment controls,

- and the fifth group included communication controls (THF and internal megaphone).

The differences between the three alternatives may be seen on the position of the communication group and the configuration of the doors control (buttons with or without warning LEDs).

On the first alternative, each of the doors control has a warning LED related to the side of the door and the controls are separated by the sounder. The communication group is placed near the light and environment buttons and the two microphones were kept in accordance with the original version of the panel.

On the second alternative, a round warning LEDs was placed on the surface of each door control and the sounder was placed on the top of the panel, not between the door controls. There is also a difference on the placement of the communication group which is presented separated from the other controls on the left of the panel. Only one microphone is available and there is the possibility of commuting the communication channel.

The third alternative presents the doors control group of the first alternative and the communication group of the second. It was selected because the position of the controls and its groups was in accordance with the sequence of activation during the driving task.

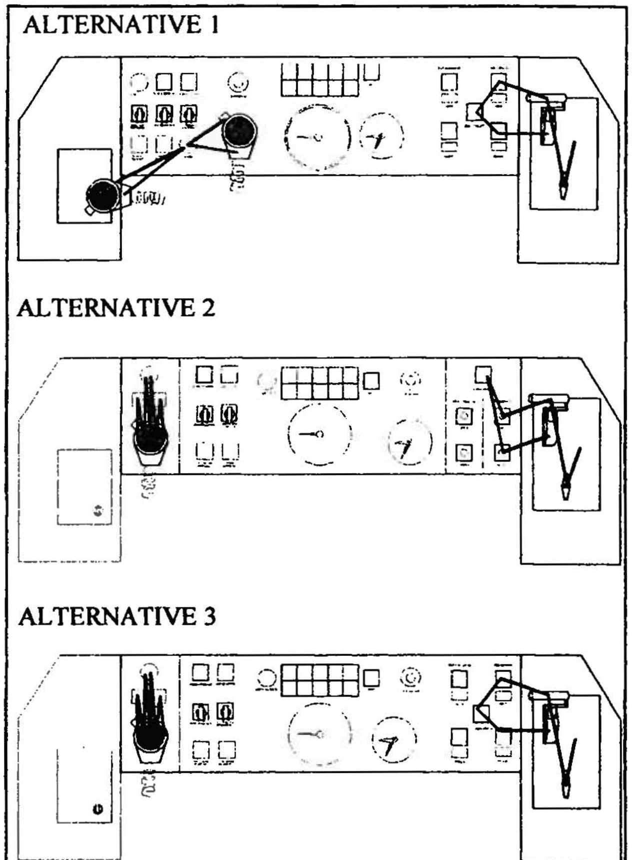

Figure 15: The three alternatives proposed for the frontal panel and the aside consoles

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