“Diagnostic system for train personnel”

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Summary

In the Netherlands Railways’ newest double -decker trainsets it is possible to monitor the train systems at train-level in order to detect malfunctions.
This information is then made available to the driver via a touch screen in the cabin. Intergo specified and designed the interaction between the driver and the diagnostic system for NedTrain Consulting. The user’s information needs w ere foremost in the design process. Aside from an analysis of the possibilities offered by the diagnostic system and the tasks of the driver, of which dealing with malfunctions is one, alongside running the train safely and on time, there were extensive consultations with the future users. Based on this Intergo determined when and how the diagnostic system could offer the driver support.
The interaction with the screen offers the driver as much freedom as possible and has been kept as simple as possible. To uch areas on the screen are large and therefore easy to operate. The malfunction warnings and advice on measures to be taken has intentionally been kept brief and to the point and is always stands out due to a different background colour. The location of a malfunction is indicated on a diagrammatic view of the train. Extra instructions about dealing with a malfunction are readily available under the button Instructions. The driver can quickly navigate back to the malfunction warning using the tabs. It is vi rtually impossible to get lost in the system, and the effort to achieve a visually restful display means that the driver is not overloaded with information on a jam -packed screen.

Four functions have been defined in the diagnostic system in order to offer the driver as much support as possible in his duties.

- Monitoring; presentation of status information.
- Semi-automatic brake test using the monitor.
- Presentation of malfunctions and the related advice on what measures to take.
- Instruction Manual; an electronic version of the rolling stock manual.

In order to test the abovementioned functionality and graphic design NedTrain Consulting held a “Usability Test” in the form of a train simulation. In the simulation a train ride was simulated on a PC platform. For the trip the driver had to prepare the train using the semi -automatic brake test and then a number of random malfunctions were generated during the trip. During the trip it was possible to request monitored information. The reactions/remarks of the driver regarding the design were used in the final design.

An implementation procedure was followed both within the maintenance organisation NedTrain Services and the operator NS Reizigers in order to train the personnel to use this new technology. At the end of the procedure an independent research agency carried out a study on the experiences with the new system by way of a survey.

The majority of the employees interviewed were of the opinion that the double -decker trainsets' system Diagnostic is a good to excellent system. Especially the display of a malfunction with the related location and advice on measures to take was found to be extremely good. The adaptation to automatically switch the screen to standby mode between 0 km/h and 40 km/h was also seen as a good thing.
The majority was confident that the reliability of the system could be trusted. The layout of the touch screen in tabs is clear and easy to use when looking up information.

From IRM to V-IRM trainsets.

DD-IRM (Double Decker Interregional Rolling Stock)
The Netherlands Railways new double-decker trains are also referred to within the organisation as V-IRM[1]. This acronym stands for extended interregional rolling stock. This train series is an improved version of the DD-IRM (double-decker interregional rolling stock) built in 1994. The name IRM stands for inter regional rolling stock which is used for passenger transport on the Dutch inter regional network (intercity transport). The rolling stock consists of a double-decker trainset with its own engine.

Each front motor carriage is equipped with a traction installation with two three phase electromotors and a static converter 1500 V/500 V DC for low voltage energy supply.
The trainset is equipped with a diagnostic system at the level of trainset.

Figure 1. V-IRM trainsets and control table showing the diagnostic screen on the right.

V-IRM (Extended Interregional Rolling Stock)

All IRM trainsets were converted to V-IRM train sets between 2002 and 2005 by Bombardier in A ken. All three and four carriage trainsets were then converted to four and six carriage trainsets respectively. The six carriage trainsets were fitted with an extra motor carriage. Aside from extending the existing IRM trainsets, new four and six carriage trainsets were also built.

During the extension of the IRM trainsets it was also possible to introduce technical improvements. One of the technical improvements was the change over from diagnostics at trainset level to diagnostics at train level, diagnostic information is available from the trainset itself and from coupled trainsets and is presented on a display in the cabin.

[1] Verlengde Interregio Materieel

Diagnosis in V-IRM

Diagnosis is the analysis of the momentary state of a device, system, trainset, or train, assisted by technical tools (computers, networks, screens, software, and PC's) without having to perform considerable assemblies or test runs, with a view to establishing the fault free operation of the device. The goal of the diagnostic system is to achieve lower life cy cle costs through better rolling stock availability and a reduction of the maintenance effort.

The IRM diagnostic system was also called the HOVIS -IRM[2]. HOVIS stands for Holec vehicle information system for IRM. This diagnostic system operates at trainset level. The information collected per system (malfunction data and monitoring data) is processed and presented by a central computer (CC) on a monochrome screen. This was located in a balcony cabinet in the ABv3/4 (middle carriage). The limitation of this system was that the information was only available in the train set where it was installed and not in coupled trainsets. Neither was the location (balcony cabinet) a very inviting location for its use.

By modernising the diagnostic system to the level of the train the monochrome screen in the balcony cabinet was replaced by a colour touch screen on the control table in the cabin. The arrival of the cabin display (touch screen) made diagnostics suddenly visible and accessible for the driver and conductor.
The screen supports the driver (MCN), engineer (MT) and head conductor (HC) in their jobs. Malfunctions are displayed to the users on this screen; at the same time it also indicates what steps are expected from the user. Monitoring information can also be queried about various systems, whereby the engineer can request more detailed information than the driver.

The user operates the application by touching the fields defined by the application on the screen with his finger. The touch screen fulfils the sam e function as a mouse on a standard PC. The display does not have a keyboard as this is not necessary for normal use by the driver, the engineer, and the head conductor. It is however possible to connect a keyboard to the display for servicing the display or application. The screen has 6 keys on the right side. The top three (marked 'MCN', 'MT' and 'HC') [3] serve to select the target group.

[2] HOlec Voertuig Informatie Systeem
[3] MCN (driver), MT (mechanic), HC (head conductor)

Technical data screen / diagnostic system

Touch Screen:	**Diagnostic System**
• PIXY INC50.03	• 3000 reports
• 110V DC	• 250 recommended measures for the driver
• 192 MB flashdisk	• 400 recommended measures for the engineer
• Low Power Pentium 133	• 3800 causes can be mentioned
• 32 RAM	• 70 different screen layouts.
• Windows 95	
•TFT-LCD 10.4" VGA Colour (640x480)	
• Conforms to EN50155	

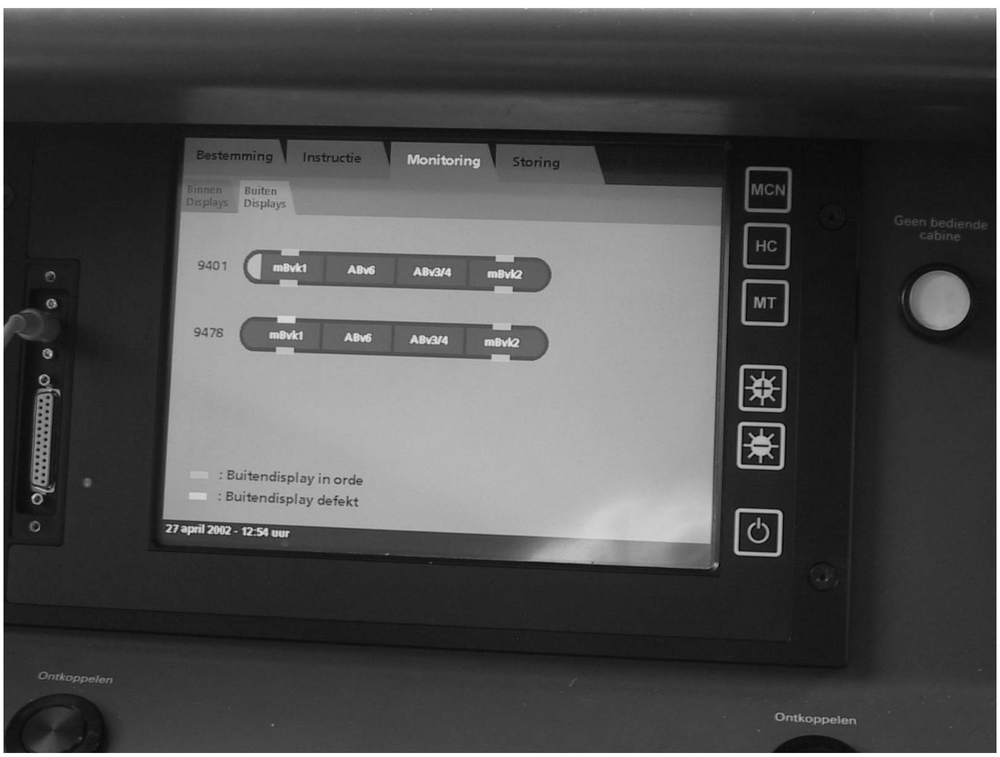

Figure 2. Colour touch screen on the control table in the cabin

Basic design of the graphic interface for train personnel

A touch screen has been installed in all cabins of the V -IRM rolling stock (2 per trainset) for t he interaction between the driver and the diagnostic system. The screens are also used by the engineer and conductor. Intergo BV specified and designed the interaction between the driver and other users and the diagnostic system for NedTrain Consulting BV.

Task analysis
In order to ensure that the information presented corresponds with the activities of the various target groups, a proposal was made for the manner of interaction with and use of the system (the dialogue), the degree of user freedom and the presentation of the information on the screen, based on the tasks of each of the users. The intention being to arrive at a user friendly interface:
• that is suitable for the task
• that satisfies the users expectations
• that is self-explanatory
• whereby the user remains the boss (it is controllable)
• the operation of which is easy to learn and whereby operating errors do not have serious consequences (error tolerance)

The diagnostic system for the V-IRM was developed to support the driver, engineer, a nd conductor respectively, in certain activities. It is an information system that is not used for controlling the trainset and does not enforce any actions. The user is always in charge. The primary area of attention was therefore the tasks for which that the diagnostic system could offer support to the various target groups.

The driver's tasks

• Preparing the shift
- preparing the train and combining trainsets
- starting up train systems
- checking train's status
- carrying out tests
- if necessary dealing with a ctual malfunctions
- communicating with traffic control about personnel deployment
- communicating with train and platform personnel about train composition, tests, malfunctions.

• Departure train
- observe departure signal and cabin signalling (departure comma nd, close doors)

• Driving the train
- observe cabin signalling from the train system
- observe infrastructure (signals, points, viaducts, stations)
- manage and check the operation of the train systems
- where necessary and possible deal with malfunctions
- run according to the time table
- communicate with traffic control about malfunctions and irregularities regarding personnel, passengers, rolling stock, infrastructure, and time table.

• Shutdown train
- shutdown the train (turn off systems etc.)
- communicate with traffic control about malfunctions of the rolling stock

The engineer's tasks
- dealing with malfunctions during passenger service
- dealing with malfunctions outside service hours
- periodic inspection before and after service.

The conductor's tasks
- input of destinations on the destination display

Overview of the various functions of the diagnostic system

Based on the analysis of tasks and the available information on the train, functions were devised to support the train driver (MCN), the engineer (M T) and the head conductor (HC) in their activities.

Driver

The screen must display a large variety of data for the driver at train level, so that the driver is informed about the status of the entire train. The screen will fulfil the following functions:

- Support preparing and checking the train.
- Automatic presentation of new malfunctions in the area of safety and operational reliability.
- Drive the malfunction warning lights and related audio signals.
- On request and only when stopped display new malfunctio ns (not in the area of safety and operational reliability).
- On request display the list of current malfunctions.
- On request display monitoring information of a number of vehicle systems in the train.
- On request display detail information about a certain ma lfunction, like:
    - display the strategy to deal with a certain issue
    - display the location in the train where the malfunction has occurred.
- On request display the training manual (the electronic version of the rolling stock manual).
- Display the time.

Engineer
The screen will show more detailed information for the engineer, this information is however only available at trainset level. The screen will fulfil the following functions for the engineer:

- On request display the list of malfunctions.
- On request display detailled information about a certain malfunction, like:
    - display the strategy to deal with the issue in question
    - display a number of relevant measuring points for a malfunction.
    - display state changes around the occurrence of a malfunction
    - display a list of possible causes for a malfunction.
    - display extra information (explanation operation subsystems, loss of function, and detection conditions) for a malfunction.
- On request display detailed information about the cause of a certain malfunction.
- On request display monitoring information of a number of vehicle systems in the trainset.
- On request display the training manual (the electronic version of the rolling stock manual).
- Set the clock within the CC.
- Administer the software versions on the display and on the CC.
- On request switch off the CC and/or the display for maintenance activities.

Conductor

The screen will also fulfil a number of functions for the conductor:

- Support for setting the destination displays inside and outside the train.
- Support for checking that the destination displays are working properly.
- Display the list of station names and their abbreviations.
- Display the help texts for setting the destination displays.

Malfunction reports handling
One of the most important functions of diagnosti cs system is detection and presentation of malfunction information. Diagnostics distinguishes between 3 different classes of malfunctions for the user group drivers, and 1 extra for the user group engineers.

Class A Safety Malfunctions
A Class A safety m alfunction, like an unlocked door during service, is reported directly via the screen on the control table supported by an audio alarm signal, also during the trip. For this sort of malfunction the train should immediately be stopped (audio signal when ope rating brake). It is necessary to deal with it immediately as the safety of the train and/or passengers is in danger. The point of the advice on measures to be taken is that the trip can be continued safely. It is not intended to necessarily to solve the m alfunction.

Class B Operational Reliability Malfunctions
An operational reliability malfunction or a Class B malfunction, like the failure of a traction unit, can lead to delays in relation to the time table or failure of a train or systems in a train. Th is type of malfunction is immediately shown on the screen on the control table. Dealing with this type of malfunction may be attended to immediately (while stopped) or be put off until later, for example during the next stop. The diagnostic system offers s upport in taking this decision by way of the advice on measures to be taken.

Class C Comfort Malfunctions/ monitoring alarms and malfunctions not related to operational reliability
Class C malfunctions are malfunctions that do not directly influence the s afety or operational reliability. It is however still important that the driver is made aware of these malfunctions as they could lead do anomalous behaviour of the train. Monitoring alarms could also be the result of shutting down a trainset incorrectly.

Class D (not relevant for the train service)
Class D malfunctions have no influence on the safety, operational reliability, or comfort of the trainset. A Class D malfunction is therefore not displayed to the driver. Class D malfunctions are dealt with by the engineer during periodic inspections or servicing. Example of a Class D malfunction: the failure of a redundant power supply.

Figure 3. Driver's list of malfunctions

Basic lay-out

It was considered essential to involve an ergonomist in the design of the basic layout and navigational options in the area of interaction between user and system, the display.

A touch screen uses a more direct method of access in comparison to the movement of a cursor with a mouse. The user points directly to an area o n the screen thereby selecting and/or activating it. The direct pointing method on the screen puts demands that the location of the screen (accessibility) and on the presentation of the control areas (size, clear confirmation of selection and activation).

The basic basis layout has been designed such that all functions can be included in the 640 x 480 pixel display and that the operation of the screen is easy and unambiguous, which is why a design with tab pages was chosen.

The screens available in the di splay are grouped behind a number of header tabs. Which header tabs that are accessible depends on the user group. The driver has access to different header tabs than the head conductor. It is in principle always possible to switch between the various head er tabs. This offers the user as much freedom as possible while retaining a continuous overview of the available functions or items of information. In some cases the application can however deactivate some tabs so that these are (temporarily) not available .
The colour of the text changes on header tabs that are (temporarily) not selectable. The header tab remains visible however so that the overall screen image remains the same. As soon as a header tab is selected by a user the background colour changes so that the user can always see which header tab is selected at any time.

A number of header tab pages (level 1) also have sub tab pages (level 2) with information that clearly belongs together (e.g. all monitoring information of a train system, information on malfunctions). These tabs are functionally identical to the header tabs: the selected sub tab has a different colour to the other tabs, and sub tabs can be (temporarily) not accessible.

There are scrollbars in a number of screens, which are used to sc roll down lists that are too long to display on the screen in their entirety.
The scrollbars consist of two arrow keys with a bar in between.
Every time that the user pushes an arrow key the list moves one line, until the beginning or end of the list has been reached.
The exception to this is the list of malfunctions for the engineer listing all malfunctions: this is paged in steps of 4 malfunctions at a time.
The speed with which the display scrolls down the list is adjustable by changing a parameter in the display configuration file

There are also a number of extra buttons that are screen specific. The function of the button is indicated by the name of the button.

The choice of colour and use of symbols in the graphic interface are based on the perce ptual environment and experience of the driver. The standard colours used on control tables, as well as the meaning of colours, have been adopted as far as possible. A closed (locked) door is symbolised by a green (safe / good) block. This corresponds to t he green light “doors closed” on the control table. Signal lights are red (danger) and yellow (caution) and these colours are reflected at Class A malfunctions (safety malfunctions) and Class B, C and D malfunctions respectively. It was also decided to use intuitive colours: blue for pressure, filled (grey) for active and transparent for not active and no pressure. Doors and valves that are closed are coloured yellow with a cross.

Dealing with malfunctions, either requested by the user or automatically rep orted by the system, requires a clear design of the screen sequencing. Although the user can interrupt the sequence of screens dealing with the malfunction to request extra instructions via a button, he must always return to where dealing with the malfunct ion was temporarily interrupted. Consistent, logical navigation is essential so that the user cannot get lost.

Figure 4. Advice screen for the drivers' user group. Location on train and trainset level of isolated axle is displayed.

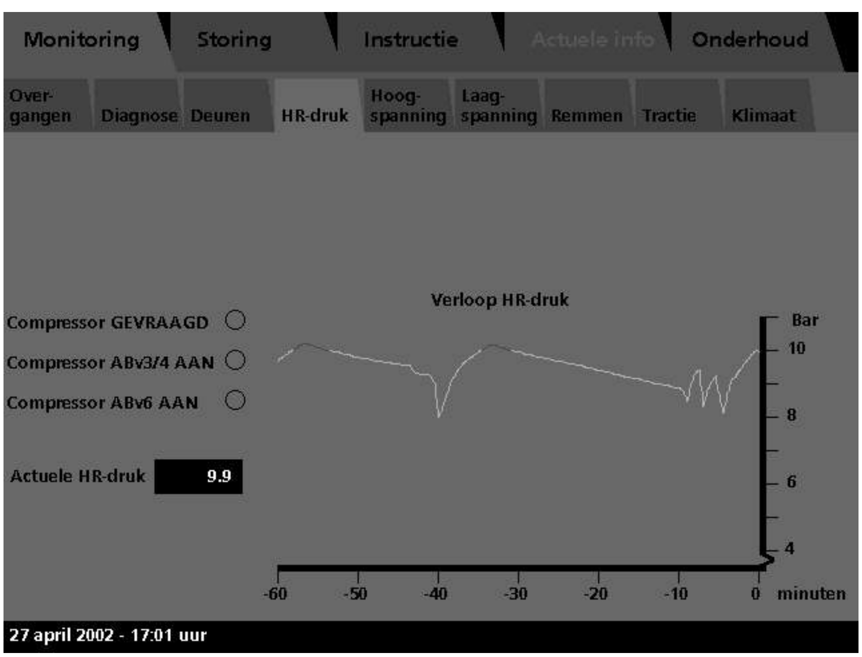

Figure 5 Monitoring screen HR pressure (usergroup engineers.)

From concept to final design

In order to finalise the basic design a participation group of about 8 drivers from various regions held monthly meetings in which all concept screens were individually discussed. All remarks and ideas of the user group were evaluated by the industry and the ergonomist and most of them were adopted.

A problem with participation groups is that in time they are no longer representative of the end users and no longer have an objective view of the design due to too much background information and their exposure to earlier concept versions. A user test with a new user group was therefore chosen for the final design of the screens.

Simulation
The method chosen for the user test was to simulate a “simple” train trip in which the engineer first had to carry out a semi-automatic brake test before starting the train journey which lasted no longer than 15 minutes, stopping at 4 stations. During the trip the engineer could monitor the current situation of the train on the displays and at least one and at most 4 malfunctions occurred in random order. After the trip, the train, which during the simulation consisted of one trainset, had to be shutdown.

User test (Usability test)

Goal of the test: to gain insight into the user friendliness of the graphic interface. Aside from the main goal a number of sub-goals were also defined.
• test the software against the specifications
• evaluate the colours and symbols used
• evaluate the layout of the screens and screen transitions (navigation)
• evaluate the presentation of malfunctions and the related advice on what to do.

Test procedure
The test procedure consisted of a virtual train ride of about 15 minutes. At the end of the trip the participant was asked to fill in a questionnaire and a short evaluation was held. The user was filmed during the test trip with the simulator with the camera focussed on the display and keyboard. All activities of the simulator and participant were logged and stored in a database. The log file can be coupled to the video recording in question. The coupling makes it possible to trace wrong reactions of the participants to events.

Results of the user test

As a result of the simulation the following adaptations were made:
• the order of malfunctions in the list of malfunctions must be according to malfunction class and within the malfunction class according to time. (was advised by the ergonomist, though not adopted in the concept)
• After a malfunction has been dealt with the system should automatically jump to the last screen displayed. (was advised by the ergonomist, though not adopted in the concept)
• after selection of a malfunction from the list of malfunctions once the malfunction has been dealt with the system jumps back to the beginning of the list of malfunctions • contrast between the various tabs must be improved.
• after resetting the energy screen the graph must also be reset.
• audio signal for malfunction must also stop when the screen is touched .
• during a brake test only brake malfunctions must be displayed, all malfunctions must be put on hold
• the brake test must be split into two parts The first part for applying the brakes and the second part for releasing the brakes.
• Operation of the scrollbar is not logical

Aside from remarks about the interface design there were also some remarks about the simulation. The simulation was also adapted after the user test and is used for the diagnostic training as training material. The CD-ROM with the simulation has also been circulated within the NS organisation as promotion for the new trains.

This was the first time that a user test in combination with a simulation had been carried out at the Netherlands Railways. This method resulted in a better de sign, in errors being discovered early on and a support platform was created amongst the users.

Addition of texts for malfunctions and advice on course of action

A qualitatively good interface ensures that that information exchange between computer and user is optimal. This also applies to the descriptions and advice on measures to be taken that are presented when malfunctions occur. The advised course of action must first of all be as short and concise as possible and adequately deal with the malfunctio n. A number of malfunctions must be dealt with during the trip and must therefore be clearly and unambiguously understandable, also for non technical users like drivers. In order to achieve this NedTrain Consulting has gone through all malfunction reports and instruction texts with a participative group of drivers in a number of sessions. A year later all texts were again gone through, at a faster rate. The same process was carried out with the engineers' target group.

Evaluative Diagnosis VIRM

Drivers

On 21 June 2005 and external company commissioned by the Netherlands Railways carried out an investigation into diagnostic possibilities (instrument viewpoint) and the drivers' willingness to work with diagnostics (cultural viewpoint). The following is a s hort summary of their findings.

In total 54 drivers and 14 professional support staff participated. The study dealt with the following 4 subjects using interviews and questionnaires:

- satisfaction and reliability of diagnostics
- how did the introduction of diagnostics go (that is not dealt with here)
- working with diagnostics
- which questions, remarks and tips from those interviewed.

The majority of the employees interviewed was of the opinion that Diagnose VIRM is a good to excellent system. Under th e heading dissatisfaction was the point that too many malfunctions were reported; "is there or is there not a malfunction in the train? ". Also the fact that the brake test incorrectly failed was seen as a negative issue. The employees were very positive a bout the fact that the system makes malfunctions visible and gives concise information about the malfunction in question; "in the event of a malfunction you no longer have to search for the location of the malfunction". The contact with the national agency for rolling stock LBM[4], this agency is a central registration point for rolling stock malfunction and offers first aid via the telephone, has also become more efficient because communication about malfunctions is more univocal, namely using malfunction codes.

The layout of the touch screen with tab pages is clear and easy to use when looking up information. The majority was confident that the reliability of the system could be trusted.

Half of the employees indicated that their work had changed as using diagnose malfunctions are clearer and easier to solve. This represents a definite time saving when dealing with malfunctions. A few regret that the work has changed. One may not and cannot do as much any more as a driver. The computer era (the electronics in the rolling stock) makes him more an operator than a driver.

Engineers

In 2004 there was an implementation process at NedTrain (responsible for the maintenance of the trainsets) for the new diagnosis system. During the process training CD -ROMs were made, workshops held and there were various meetings. During these meetings discussions were held with representatives of the various workshops about the diagnostics system, the effect of diagnostics on their activities and what any board – land communicat ion, whereby diagnostic data is available before the trainset rolls into the workshop, means for the maintenance process. The reactions to the diagnostic system (de interface) were very positive, in spite of the fact that the engineers were not directly involved in the design. During the workshops the diagnostic system and the advice on measures to be taken were tested in practice. Points that arose during these workshops were implemented in cooperation with Alstom. Paging through the list of malfunctions p er page, because the list of malfunctions for the target group engineers is longer than for the driver, is one example of an improvement.

A diagnostics team was formed for the implementation of VIRM diagnostics in the workshops. There were representatives of each workshop in this diagnostics team as well as a representative from the LBM. In the monthly meetings mainly the advice on measures to be taken was gone over once more and practical experiences were added to the advice on measures to be taken.

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[4] Landelijk bureau mate rieel

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