Rail to Digital automated up to autonomous train operation

D38.1 – Training guidelines, operational guidelines and instructions, training material

Due date of deliverable: 31/12/2025

Actual submission date: 22/09/2025

Leader/Responsible of this Deliverable: **Nederlandse Spoorwegen**

Reviewed: Y

Document status		
Revision	Date	Description
01	13/08/2025	First issue for WP-review
02	22/09/2025	Incorporation of WP38 review comments
03	14/01/2026	Incorporation of JU review comments

Project funded from the European Union's Horizon Europe research and innovation programme		
Dissemination Level		
PU	Public	x
SEN	Sensitive – limited under the conditions of the Grant Agreement	

Start date: 01/12/2022   Duration: 36 months

ACKNOWLEDGEMENTS

REPORT CONTRIBUTORS

Name	Company	Details of Contribution
Jeroen Braakman	NS	Author, Task Lead
Eric van Schadewijk	NS	Author
Lotte Lammers	NS	Author
Ton Visser	NS	Review

Disclaimer

The information in this document is provided "as is", and no guarantee or warranty is given that the information is fit for any particular purpose. The content of this document reflects only the author's view – the Joint Undertaking is not responsible for any use that may be made of the information it contains. The users use the information at their sole risk and liability.

Disclaimer – AI Tools

During the preparation of this work, artificial intelligence (AI) tools have been used to assist with translation, rephrasing, enhancing readability and supporting the formulation and structuring of content. The content, analyses, conclusions, and interpretations presented in this document were developed exclusively by the authors. After using this technology, the authors reviewed and edited the content as needed and take full responsibility for the content of the publication.

EXECUTIVE SUMMARY

This study describes the training guidelines and materials that were developed to teach train drivers prior to and during their first sessions of remote driving as part of the R2DATO 38.2 study and the other tasks in which remote driving is performed. The training materials are based on a combination of sources ranging from previous remote driving studies in the automotive and railway industries, technical descriptions of the ROC and interviews of previous remote drivers. Each of the sources has been analysed and relevant themes related to the training of remote drivers were identified and categorized.

A training program was designed that consists of three phases; (1) a written briefing that is distributed to the student prior to the training, (2) a verbal instruction that is given by a trainer prior to the student's first remote driving run, (3) practical lessons during which the student performs three runs of remote driving while being actively coached by a trainer. This program was then applied as a training for all remote drivers that participated in the R2DATO 38.2 demonstrator. Training feedback indicates that trainees quickly acquire the basic remote driving skills. However, challenges remain in areas such as situational awareness, accurately estimating distances and managing braking curves to target locations, suggesting the need for targeted focus in future training iterations or potentially technical system enhancements.

ABBREVIATIONS AND ACRONYMS

ATO	Automatic Train Operation
ATP	Automatic Train Protection
ATB	Automatische Trein Beïnvloeding (Dutch class-B ATP System)
BTW	Bureau Tijdelijk Werk (Temporary work provider for NS-drivers)
GoA	Grade of Automation
HTO	Human-Technology-Organisation
NS	Nederlandse Spoorwegen
RD	Remote Driver
RI&E	Risk Assessment & Evaluation
ROC	Remote Operation Centre
RTO	Remote Train Operation
RU	Railway Undertaking
R2DATO	Rail to Digital automated up to autonomous train operation
SoM	Start of Mission
S&O	Service & Operatie (Train driver department within NS)
SME	Subject Matter Expert
SNG	Sprinter New Generation (Train that was used in the RD-studies)
TRN	Train Running Number
TTC	Train Test Centre (of NS)
UI	User Interface

TABLE OF CONTENTS

1 INTRODUCTION

Task 38.1 *"Training of involved staff"* is part of R2DATO WP38 titled *"Automatic Stabling, Shunting, and Non-commercial runs Demonstrator"*. The aim of this work package is to test the different technical enablers for automatic stabling, shunting and non-commercial runs.

The demonstrators of WP38 have been designed to show the performance of ATO and remote driving technologies in an operational environment, integrated in an existing trainset that operates on public tracks. This setup introduces a new working method for operational staff, with procedures that differ from regular train operations.

In order to properly prepare for the demonstrators of WP38 it is important to establish training materials for the involved staff to supervise and remotely control the train movements in a safe and efficient manner. This Deliverable *"D38.1 – Training guidelines, operational guidelines and instructions, training material"* is the outcome of Task 38.1 and describes the training material, operational guidelines and instructions that were developed for the WP38 demonstrators. The exact description of this task is mentioned in the Grant Agreement:

"Before actually being able to remotely supervise and control a train, we will identify the needs for involved staff (the remote controller/supervisor and the traffic controller) to be able to supervise and remotely control train movements, and train the staff involved. This task will also identify which elements are train-type-specific and which elements are generic. Therefore, we need to create training material and then train the staff involved in the execution of each of the other tasks."

1.1. PROJECT RELATIONS

This task has a strong relation with the other tasks within WP38, specifically for the demonstrators that are being performed within:

- Task 38.2 *"Stabling a train and bringing a train to the station by remote control (GoA1)"*
- Task 38.6 *"Remotely controlled coupling and uncoupling"*
- Task 38.7 *"Moving a train within a yard by remote control (shunting)"*

These demonstrators involve the tests in which the tasks of remote driving are performed by regular train drivers with no previous experience of RTO. The training materials therefore serve as a pre-requisite for the performing of these tasks. This document specifically does not apply to the other tasks within WP38 in which remote driving is not applied or is performed by experienced remote drivers.

Considering that the technical solution and the majority of the research environment for the remote control demonstrator of NS is the same in all tasks of WP38, it will only be described once as part of deliverable D38.2. The other deliverables will not duplicate these chapters but instead refer to D38.2 and mention any differences if applicable.

1.2. GOAL

The goal of this deliverable is to establish a collection of documentation and procedures that, when combined, form the training program and operational guidelines for some of the WP38 stabling/shunting demonstrators. The documentation consists of:

- A **briefing document** that is used to inform the drivers prior to their first experience with remote driving.

- **A guideline for verbal instructions** to be used by the trainer to teach the remote driver.

- The **operational plan** for the performance of training days and applicable procedures.

While the original scope of task 38.1 only describes the development of training materials, it was deemed valuable by the task participants to also incorporate the key takeaways of implementing the training materials. These insights can be relevant for both the development of future remote driving systems, as well as the training of future remote drivers. Therefore, a dedicated chapter on training feedback is included.

1.3. METHODOLOGY

The development of training materials is based on different research methods which primarily consist of literature review, observations, and expert interviews. Literature review is performed for several purposes:

- The **technical design** of the demonstrator solution is studied to determine topics that should be addressed during the training and operational solution of the demonstrator.

- **Reports of previous RTO-tests** are studied to investigate previously established training materials and relevant lessons learned that should be taken into consideration for the new training materials and operational guidelines.

- **Documentation of similar applications of remote operation in the car industry** are used to identify lessons learned from a higher TRL-solution with operational use-cases.

Expert interviews are organized with subject matter experts that were previously involved in RTO-tests, to identify additional topics that may be applicable for the training materials and operational guidelines. The (subject-matter) experts referred to in this study consist of train drivers and specialists that were involved in the design, operational performance and evaluation of previous ATO and remote driving research projects. The train drivers have previous experience (10-20 days) of operating a train remotely. The combination of direct involvement and hands-on experience ensures that their input is valuable and representative for this study.

Upon completion of the literature review and the expert interviews, the output has been ranked by subject matter experts on applicability and relevancy for the current demonstrator solution and consolidated into a training program. This training program is then used to train the new train drivers that will be operating in the role of Remote Driver (RD) prior to performing the D38.2 demonstrator. The results of this analysis affect only the relevant training and operating procedures and are not incorporated in the design of the technical solution in this demonstrator.

The research questions that will be studied as part of task 38.2 also investigate the human-factors related aspects of driving remotely. The outcome of this qualitative study may also retrospectively be relevant to the training materials and operational guidelines of the current and future demonstrators. These lessons learned will however not be included as part of this document due to different timelines.

1.4. APPLICABLE ENVIRONMENT

The training materials in this document are designed specifically for the R2DATO WP38 demonstrators related to the application of Remote Driving and ATO-GoA4 in stabling / shunting operations. This demonstrator will take place on the Dutch mainline railway network on the route between Hengelo and Enschede as shown in Figure 1.

The test route consists of two start locations (Enschede and Hengelo) that each consist of a train station and a shunting yard next to the station. The total test trajectory spans a length of approximately 10 kilometres, consisting of mixed traffic lines with operating speeds up to 125 kph. Other characteristics of this route include one intermittent train station (Enschede Kennispark) and several protected level crossings. During the demonstrator, the train will be operating between Hengelo and Enschede, attending either the shunting yard or station platforms of each station.
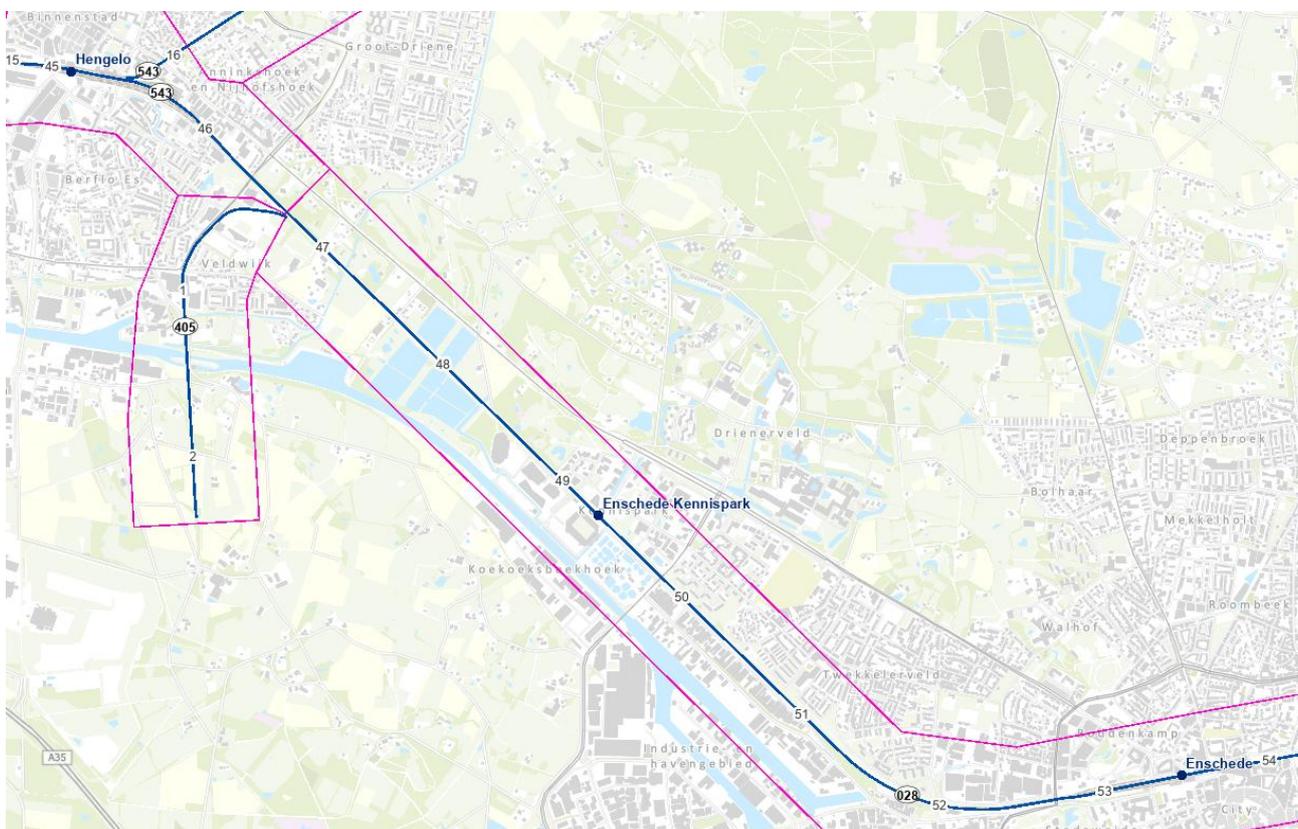
Figure 1: Overview of the Hengelo-Enschede railway line

The test environment also spans the Remote Operation Centre (ROC) which is located in the NS office in Utrecht. The ROC is depicted in Figure 2. The ROC consists of a dedicated room that contains a steering table, which represents the layout of the physical train. From this steering table the RD is able to operate the train remotely similar to how they would operate from the driver's cab during regular operations.

Testing is carried out on an NS SNG-type train, produced by CAF. The train has been retrofitted with RTO, ATO-GoA2 and ATO-GoA4 technologies and has been granted a derogation by Dutch regulator ILT.

A more detailed description of the demonstrator, the test environment, the performed research, and the technical solution is provided in D38.2.

Figure 2: Overview of the Remote Operation Centre and Steering Desk

Due to the nature of the demonstrator's technical solution and the applied environment, the tests are subject to the specific operating rules as described in the derogation, Dutch railway regulations and NS internal operating guidelines.

Several characteristics of the demonstrator environment may differ from a future implementation of remote driving and may not be applicable for other operational concepts or environments. Specific characteristics of this demonstrator include:

- **Technical solution:** The demonstrator is executed with a prototype that is based on the preliminary design of remote driving and ATO-GoA4 solutions. This prototype is not fully representative of a future, full-scale TSI implementation of these technologies. A detailed overview of the technical solution is described in D38.2.

- **Operating environment:** The demonstrator will take place on the Dutch railway network and is therefore subject to national operating rules and legislation, which differ from other countries.

- **Railway Undertaking (RU):** The demonstrator will be conducted with NS as the responsible operator and is therefore subject to NS's testing and operational policies, which may differ from the policies of other RUs.

1.5. TARGET AUDIENCE

The training materials and operational guidelines developed as part of this deliverable will be used by the train drivers of NS who will act in the role of RD as part of the D38.2, D38.3, D38.6 and D38.7 demonstrators. The train drivers participating in this experiment have no previous experience in the role of RD. The RD is responsible for operating the train remotely during the D38.2 tests. Personnel participating in the experiments are assigned from one of the following three departments:

- **TreinTestCentrum (TTC):** Drivers from NS's department for test activities with trains. These drivers are used to operating in unusual scenario's and handling new systems.

- **Bureau Tijdelijk Werk (BTW):** An internal NS department that provides work for train drivers temporarily unable to perform their regular duties due to personal physical or mental circumstances.

- **Service & Operatie (S&O):** The department responsible for the regular day-to-day train operations of NS.

The train drivers of TTC have been assigned by the planning department without specific selection criteria, while the train drivers of BTW and S&O enrolled themselves voluntarily for this experiment. All train drivers involved in the experiment were qualified train drivers, holding specific qualifications for the used train asset (SNG) as well as the necessary certificates for operating in the test environment. No additional criteria or randomizations were applied in the selection process.

Some of the TTC drivers involved in this experiment have previously been involved in remote driving tests in the role of safety driver.

All drivers in this experiment had completed their driver training and had at least one year of experience operating independently. While some drivers were relatively new, others had over 20 years of experience as a train driver. The exact statistics of the participants were not collected during this study.

During this study, the student will interact with the trainer who is located alongside them in the ROC and is responsible for teaching the student on the study setup and the skills required for remote driving. The student will also interact with the safety driver, who is inside the train and responsible for the safety during the study. This interaction takes place using a Teams-call and consists of safety-related aspects of driving, i.e. announcing attentions and observed signals by the student.

2. INPUT ANALYSIS

This chapter describes the collection of input that provides the basis for the training guidelines, operational guidelines, and training materials developed as part of this Task. It consists of a literature study of relevant sources related to RTO and interviews with experienced (remote) drivers.

2.1. LITERATURE STUDY

Previous experiments applying remote driving technology have yielded valuable insights related to the training of remote drivers. Several (in-house) reports on these experiments were made available by WP38.1 participants (SBB, NS), and additional reports were collected through a literature study of public sources.

As an initial exploration of relevant content, a qualitative analysis of the collected literature was conducted. During this process, relevant insights were selected that explicitly or implicitly refer to knowledge, skills, or contextual factors relevant to the remote operation of trains. These excerpts were then grouped thematically based on content similarities, without the use of formal coding software. Although this approach is inherently subjective, it provides a pragmatic first basis for curriculum development. The excerpts that were selected will further be referred to as "Relevant Themes," and will be labelled in the format of: "RT-<DOCUMENT NUMBER><ID>"

The next paragraphs describe the different sources that were used in this literature study, for each of the documents the relevant contents related to the training or operational guidelines of remote drivers are extracted into Appendix 5.1.

2.1.1. NS Remote Driving Human Factors study

This report [1] describes the results of a NS study on the human factors implications of RTO, focusing on how replacing the traditional train cabin with a remote workplace affects the train drivers' task performance and experience. It presents the results of three experimental studies examining the effects of latency, image presentation and absence of haptic and auditory feedback on operational performance and driver workload. The studies were performed in simulated research environments.

Important topics that were presented in this study include the effects of latency on remote driving performance, the adoption of a more defensive driving style and difficulties of speed estimation when driving remotely. It also states that the lack of haptic and auditory feedback did not affect the task performance. An overview of all topics is included in Appendix 5.1, labelled [1].

2.1.2. SBB Remote Operation POC

This document [2] describes the results of a study on the feasibility and Human-Technology-Organisation (HTO) aspects of remote train operations as a fallback for ATO-GoA4 and was performed by SBB and the research institute DLR. It examines the use of a remote-control desk to operate locomotives from a control centre, applying different test scenarios with experienced train drivers to investigate topics such as safety, usability, and workload during remote shunting tasks.

Many HTO-recommendations were discovered during this study, several of which are specifically for the training of remote drivers, for example the training program containing both the technical and procedural aspects of remote operations, as well as incorporating the limitations of remote driving compared to onboard driving. An overview of all topics is included in Appendix 5.1, labelled [2].

2.1.3. Remote Driver study of Oxford

This study [3] was performed by Oxford to investigate the driver-related aspects of remote operation. It analyses previous studies on the topic of remote driving, as well as interviewing participants that are experienced in operating cars remotely. The results based on autonomous car fallback operations may not be fully comparable to the railway sector but could provide relevant topics of attention.

The outcomes of this study provide a lot of measurement tools that can be interesting for the design of the D38.2 performance and human factors study. Several human performance insights are mentioned that may also apply to remote train operations such as safety challenges with connectivity loss, detachment of physicality of actions and high stress levels for participants. It also mentions the importance of teaching communication protocols and operating procedures for degraded modes as part of the training. An overview of all topics from this study is included in Appendix 5.1, labelled [3].

2.1.4. Identification and Classification of Human Performance related Challenges during Remote Driving

This study [4] analyses safety related events that were encountered by remote drivers during their fallback operations for autonomous vehicles in Las Vegas. The relevant safety events were analysed to identify lessons learned and training topics.

The outcomes of this study provide measurement tools that can be interesting for the design of the D38.2 performance and human factors study. It also mentions important topics for the remote driver study, including specific training on controllability of the solution and separate training for the specific operational domain in which the solution will be applied. The performing of braking manoeuvres is mentioned as a challenging topic for remote drivers due to the limited haptic feedback and perception of distance and speed. An overview of all topics from this study is included in Appendix 5.1, labelled [4].

2.1.5. Technical Solution Description: Remote Operation Centre

This NS internal document [5] describes the technical solution of the ROC, the user interfaces (UI) and different operating procedures related to the technical solution. The nature of this solution results in specific operating procedures that are relevant for the training of the remote driver.

The different characteristics and operating procedures of the steering desk have been included in Appendix 5.1, labelled [5].

2.2. SUBJECT MATTER EXPERT INTERVIEWS

In addition to the known literature related to remote driving, all WP38 participants were asked to provide relevant input of SME's that have previous experience related to the technology of remote driving. This request was done in the form a written questionnaire. There have been four respondents who participated in the questionnaire, one SME of SBB and three SMEs of NS. The interview format can be found in Appendix 5.2.

The SME's that responded to the questionnaire have different levels of experience, varying from one day of experience with remote driving up to several years of participating in remote driving projects.

The following chapters summarizes the input of the SMEs for each of the interview questions.

2.2.1. What topics should a new remote driver be thought prior to their first experience with remote driving?

Drivers mention the similarities between remote driving and regular train operation, the main difference being the user interfaces. The most important topics according to the SME's are:

Training on elements that are **new** in the ROC, compared to the physical design of the train cabin. For this specific solution that includes the presence of digital camera views, camera selection buttons, the presence of a 2D-Map and the functionality of logging in. These are features unfamiliar to the driver based on their regular driving experience.
Training on elements that are **different** in the ROC, compared to the interface in the train. For example, the change in the point of view of the driver, network delays and user interfaces (i.e. button that is visualized on a screen, compared to a physical button).
Training on elements that are **missing** in the ROC, compared to onboard. For example, the lack of GSM-R, haptic/audio feedback or the option to perform brake tests.
Training on scenario's that are handled **different** when operating remotely, or when operating in a test environment with a safety driver onboard. This includes how to manage loss-of-connection.

2.2.2. How would you design the practical lessons for a remote driver? What topics should they encounter?

All SME's mention the need to gain hands-on experience by accumulating operational hours of using the remote driving technology. This includes the performing of basic tasks that drivers are expected to encounter during their job, such as driving on a shunting yard or coupling/uncoupling. This should be done under supervision of an experienced colleague.

SME's mention that the best way to get familiarized with remote driving is to gain hands-on experience of using the technology under supervision of an experienced user.
The training should allow the driver to encounter all tasks that are necessary for their regular work. This could include tasks such as driving on a shunting yard or coupling/uncoupling but also specific "unhappy" scenarios such as encountering an unexpected obstacle such as a brake shoe.
Some SMEs recommend including a theoretical training prior to the practical lessons.

2.2.3. What did you perceive as most challenging when first getting familiarized with remote driving?

All of the SME's mentioned the difficulty of comparing the perspective of the remote driving compared to the onboard reality, specifically when estimating distances, comparing field of views or predicting braking curves. Some drivers also mention the lack of visibility and lack of G-forces / acceleration.

> SMEs recommend including training elements that address the difference between the remote "experience" and the onboard "experience" of the drivers. Specifically, aspects such as distance/positioning estimations.

The different recommendations of the SMEs for the training program have been included in Appendix 5.1, labelled [6].

3. TRAINING DEVELOPMENT

This chapter describes the development of training materials, based on the input collected in the literature review and driver interviews of Chapter 2. The relevant themes will be analysed by experts, resulting in a filtered subset for each of the three training phases. This is then further processed into training documents or trainer guidelines.

3.1. TRAINING SET-UP

The instructional design for the remote driver training follows a structured three-phase approach: (1) theoretical briefing, to activate prior knowledge and provide context; (2) verbal instruction, where procedures and system functionalities are explained by a qualified trainer; and (3) practical sessions, where learners apply the knowledge in realistic scenarios. This sequencing utilizes principles of direct instruction and cognitive apprenticeship, ensuring a gradual transition from understanding to autonomous performance.

1. The **theoretical briefing** consists of a document that is distributed to the test participants two working days prior to their participation in the remote driving experiment.

2. A **verbal instruction** is provided by experienced trainers prior to the start of experiments. This is a free-format, one-on-one instruction to familiarize the driver on the remote driving environment and test set-up. The trainer uses a list of training topics to be addressed during the instruction.

3. The **practical lessons** consist of the remote driver partaking in remote driving runs, under the supervision of experienced trainers.

3.2. RELEVANT THEME EVALUATION

The relevant themes for the training of remote drivers form the basis of the three different training phases. Each theme was assessed on its relevance to the objectives of this experimental phase and mapped to the most appropriate stage(s) of the training. The evaluation considers three main factors:

1. **Practical applicability** within the current prototype system and test setup.

2. **Training necessity** for safe and meaningful participation in the experiment.

3. **Exploratory value**, where a lack of prior instruction might reveal insights into RD behaviour or usability.

Themes that were considered essential for understanding the system's basic functionalities and context were included in the **theoretical briefing**. Topics that required verbal explanation or contextual framing by an expert were allocated to the **verbal instruction** phase. Finally, themes that could best be internalized through practice and experience were integrated into the **practical sessions**.

It is important to note that some topics which may be relevant in a future operational context were deliberately not addressed or prioritized during this test scenario. In some cases, this was because these aspects are precisely what we aim to explore and better understand through the experiment. Prematurely accounting for them would risk influencing or biasing the outcomes of the investigation.

In other cases, specific topics could not be tested due to current technical limitations or because they fall outside the scope and objectives of this research campaign which is mainly focused on

technical feasibility of a prototype solution. These constraints were taken into account when designing the training program and defining the testing parameters.

An overview of the relevant themes and the evaluation can be found in Appendix 5.1.

3.3. DEVELOPMENT OF THEORETICAL BRIEFING

The theoretical briefing was drafted by subject experts of NS to inform the test participants on the purpose of the tests, the safety measures, the schedule for the experiment and generic information on the technical solution. It is important to provide train drivers with basic information about the research and the expected tasks before they participate, especially when they are operating a train remotely for the first time. Clear communication about the purpose of the study, how the remote operation will work, and what is expected of them helps ensure that they feel prepared and confident. It also allows them to give informed consent and ask questions in advance. This transparency supports both the safety of the operation and the quality of the research, while respecting the drivers' professional responsibilities and well-being. The theoretical briefing has been included in Appendix 5.3

In addition to the theoretical briefing, the participants were mailed a copy of the informed consent form that is used for human factor studies within NS, a copy is included in Appendix 5.4.

3.4. DEVELOPMENT OF VERBAL INSTRUCTION

The verbal instruction was designed as a semi-structured 30-minute session in which the trainer further instructs the student on the set-up of the experiment, the technical solution of the ROC and the operational procedures. This instruction was planned prior to the driver's first trip. This verbal instruction is based on pre-determined talking points that are addressed by the trainer in an interactive setting. Thirty minutes was considered sufficient to provide the instruction while also allowing time to answer any questions the student might have. While it does allow the student to observe and interact with the remote desk, it is not (yet) operational at the time of the verbal instruction.

An overview of the trainer' briefing and talking points has been included as Appendix 5.5

3.5. DEVELOPMENT OF PRACTICAL SESSIONS

The practical session is where the RD will be seated behind the now operational remote desk and perform their first task of remote driving. This starts when the train is connected but still stationary, allowing the RD to operate the camera's and perceive the different user interfaces. The communication with the safety drivers on the train is also initiated so the RD is introduced to the way of communicating during the study.

When the departure time is met and the train has received the movement authority, the driver will start the first of three training runs. These training runs consist of the student operating the train remotely while under supervision of an experienced trainer. The three training runs are based on the concept of decreasing assistance and increasing responsibilities for the remote driver. The total driving time is approximately 10 minutes for each test run and includes stopping at an intermediate station and driving inside of shunting tracks. An important topic of the practical sessions is to allow the RD to build trust in the system, which is especially done during the practical lessons.

An overview of the trainer' briefing and talking points for the practical sessions has been included as Appendix 5.6.

3.6. FUTURE TOPICS

The topics described in this chapter are not included in the training for this prototype, but are expected to be relevant for the training of drivers that will act as a remote driver in an operational scenario. This specifically applies to any aggravating situations related to remote driving.

1. Reliable verification of the location at start-up, in particular due to limitations in the field of view and the image quality which may be reduced compared to reality. Restrictions due to weather and daylight conditions as well as illumination of the vehicle's location and backlight situations would also have to be addressed.

2. Method of granting moving authority, or signals to be observed (e.g. shunting signals in front of/behind the front of the train, close to the front of the train, etc.). Note that the traffic controller must be consulted in the event of uncertainty.

3. Training of communication options with partners, in particular traffic controllers, staff on the track and on the train.

   Training regarding the clarity of communication with the traffic controller. In particular, verification of which journey is meant precisely and which location the journey is actually located.

   Training for the Moving Authority on possible hazards in the event of misinterpretation of the location or the valid signal.

4. Instructive processing of possible safety-relevant events as a learning effect from possible or actual errors.

5. Training on incident perception and incident management incl. derailment, train separation, recognition of emergency calls etc.

6. Training on how to recognise and use road gradients especially for coupling at short distance. (Tips and tricks from other remote operators/ learn best practice)

4. TRAINING FEEDBACK

The materials as described in the previous chapters have been applied during the training of the train drivers that participated in the Task 38.2 remote driving experiments. The training was provided by three different trainers of NS. This chapter contains observations that the trainers made while giving the training to the new remote drivers.

- All drivers were quickly able to perform the **basic driving function** (i.e. giving traction / braking) when first introduced to remote driving.

- When first introduced to remote driving, some drivers appeared to remain nervous or attentive for a long time, whereas others appeared to be comfortable with driving remotely within minutes after their first departure.

  - o This might indicate different training needs for drivers on how long they require supervision before being confident on driving remotely. Should be further studied when designing training programs for remote drivers.

- It was difficult for most drivers to estimate distances to reference points outside of the train, for example when estimating how far they are positioned away from the end-of-track buffer or a reference point on the station platform. It was helpful for the participants to receive feedback during their training on the actual position of the train, they managed to incorporate this feedback to improve their positional awareness in future runs.

  However, this issue did not apply to on-track positioning relative to other trains, which the drivers considered easy using the coupler-camera perspective.

  - o It is recommended to address relative positioning, with real-world feedback as part of future training programs.

  - o Relative positioning can be improved by using distance-measuring tools (on-track distance to buffers) or side-view camera perspectives in future technical solutions.

- It is difficult for drivers to estimate the braking curve; this was encountered mainly when braking from a high speed to standstill.

  - o It is believed that the difficulties when braking from a high speed to standstill is caused by a difference in the response of the braking lever in the ROC compared to onboard. When selecting the minimal braking position in the ROC, a higher braking effort is initiated compared to when applying this lever position during regular operation of the train (which the drivers are used to). This issue can be mitigated either in the design of future ROC solutions (to mimic the onboard response of UI elements) or incorporated into training to make the drivers aware of the difference and the behaviour of braking when performing remote operation.

- Drivers mentioned the difference in the experienced operating speed from the perspective of the ROC compared to being onboard of the moving train. During regular operations they would not always monitor the speed indicator but also rely on cognitive speed estimation using external cues such as outside views, acceleration forces and sound to estimate the current speed or if they are approaching a target speed. This is different in the ROC where the camera's point of view is different and sound & acceleration cues are non-available. Several occurrences of overspeed were observed during the study.

- With cognitive speed estimation being more difficult when driving remotely, the placement of the speed indicator becomes more important in the ROC.

- It is recommended to further study if the cognitive ability of drivers to estimate their speed while driving remotely improves when becoming more familiarized with the technology.

- It may be beneficial to include additional cues to support the driver's cognitive ability to determine their speed. This could include audio, and haptic feedback.

- It should also be considered to account the missing vestibular, tactile and proprioceptive feedback as topics of the driver's training. Considering that these topics are different when you are not onboard of the moving train. While all of the drivers involved in this study have certificates of local track knowledge, some drivers were very familiar with the test trajectories whereas others have rarely operated on the trajectory during their career. The researchers noticed that drivers that are more familiar with (physical) driving on the test trajectories were able to apply this knowledge for targeted searching - i.e. using the zoom feature of camera's - of risk areas and elements of lineside signalling. Drivers with less experience would instead opt for a more defensive driving strategy and/or spend more time searching for important external cues.

  - It is recommended to further study the requirements of local track knowledge for remote drivers.

- Within the test solution the dead-man switch was integrated as a physical button on the steering desk, contrary to the pedal input which is used on all NS-trains. The indicator for the dead-man switch almost expiring is also integrated by an on-screen visual indicator instead of a dedicated light. This different configuration was unfamiliar for the drivers and resulted in several system interventions.

  - It is recommended to further study the requirements of the design of ROCs compared to the onboard steering desk.

- It was observed that the training days appeared to be very intense for the involved drivers, with noticeable fatigue at the end of the training / research runs. The training and research runs would usually span approximately 4 hours of tasks including breaks between runs and one break that lasts for at least 30 minutes. This fatigue is remarkable considering the tests taking place during daytime and the test day being 4 hours, compared to regular train driver shift spanning 8 to 10 hours.

  - The effects of remotely operating a train on a driver's attention span and fatigue levels may be different compared to onboard operation, this impact is not yet fully understood and requires further investigation. It is important to study how remote driving influences mental workload, vigilance, and overall alertness to ensure a safe operational concept of remote operations.

  - Remote operations can be categorized as a desk-job and is therefore a very different work environment compared to onboard train driving. The requirements of such a change in work environment should be further studied.

- Sending the briefing instruction only two working days in advance, without any allocated time to read it may have given the participants insufficient time to properly study the document.

- It could be considered to allocate dedicated working hours to the RD for properly reviewing the document.

- This may also allow the opportunity of sharing additional information, for example the topics that are shared in the verbal instruction.

It is expected that future projects will design their own training materials based on the specific needs of the technical solution and operating context. While the majority of the research materials will be specific, it is recommended to address both the topics of the identified training materials (Appendix 5.3, 5.5), combined with the lessons learned and recommendations provided in this chapter.

5. APPENDIX

5.1. RELEVANT THEMES & EVALUATION

See the table in the next pages.

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-1A	[1]	The study describes that delays up to and including 600ms do not have any serious effect on driving and shunting performance of the remote operator. However, there seems to be a slight delay of experienced performance at 1000ms.	The remote driver should be made aware of the possibility of high latency affecting their driving performance. They should be trained on how to recognize and respond in case such situation occurs.		x	x
RT-1B	[1]	The study describes that drivers generally choose a defensive driving style when first introduced to remote driving. It is unclear what driving strategy is applied by drivers that are more familiar to remote driving.	Specifically not addressed during training, to observe the natural response of participants when driving remotely. This is part of the D38.2 human factors study.			
RT-1C	[1]	Situation awareness seems to be affected as drivers experience a different speed between the 6mm regular and 25mm zoomed camera views and find it difficult to estimate the actual speed of the train.	The usage of different camera views is a new way of working for the driver and should therefore specifically be addressed during training. This includes the impact of having different views on the speed estimation. It can be demonstrated during the training runs by having the driver switch camera perspective while driving.		x	x
RT-1D	[1]	Motion Sickness might be an issue for remote drivers.	The remote driver should be made aware of the possibility of motion sickness affecting their driving performance. They should be trained on how to recognize and respond in case such situation occurs. Additionally, the presence of motion sickness is further analysed as part of the D38.2 Human Factors study.		x	x
RT-1E	[1]	There is no indication that the absence of haptic and auditory feedback led to a severe decrease in task performance. Task load, however, does show differences between the various conditions. The absence of both auditory and haptic feedback increases the experienced task load. The researchers therefore conclude that with the absence of feedback it takes more cognitive resources to perform the same task with the same performance. This is supported by the interviews, in which train drivers expressed their preference of having audio or haptic feedback. Longer rides with deprivation may lead to decrease of task performance as a result of longer exposure to higher mental load.	Specifically not addressed during training, to observe the natural response of participants when driving remotely. This is part of the D38.2 human factors study.			
RT-2A	[2]	The image quality of the remote desk is crucial for the perceived reliability, availability and safety of the system. The lack of circumferential visibility or additional information (e.g. information about downhill/uphill gradients) was something the test candidates addressed.	The usage of different camera views is a new way of working for the driver and should therefore specifically be addressed during training. This includes the field of view compared to their regular in-cabin position.		x	x

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
			It can be demonstrated during the training runs by having the driver switch camera perspectives.			
RT-2B	[2]	The test candidates estimated in some cases the speed of the remote-controlled movement up to 50% slower compared to an on-site movement. A reason for that was the more defensive driving behaviour. While driving at night, the speed was even lower due to the restricted visibility.	While the speed estimation will be addressed during training, driving style/driving behaviour is not addressed to study the natural response of drivers when driving remotely.		x	x
RT-2C	[2]	Future remote operators must be specifically trained: · Develop an understanding of the technical system and processes (remote control) · Build up expertise on the remote control desk · Gain experience at the remote control desk and in real operation	Very relevant for training. Topics to be addressed during pre-briefing, verbal instructions and training plans.	x	x	x
RT-2D	[2]	The transmission of the acoustics from the driver's cab to the remote control desk is desired. An additional improvement would be to provide a possibility to interact with the staff on-site. For example, to give feedback to the hand signal and acknowledge that the people were noticed.	Specifically not addressed during training, to observe the natural response of participants when driving remotely. This is part of the D38.2 human factors study.			
RT-2E	[2]	Estimating the distance to obstacles is challenging and requires experience with the different cameras for close and normal range. Possible sensors for displaying distances to obstacles (vehicles, drag shoes on the track, buffer stop, etc.) or signals could be useful. Front cameras with adaptive cornering and zoom function would be a way to improve the system.	The usage of different camera views is a new way of working for the driver and should therefore specifically be addressed during training. This includes the distance estimation compared to their regular in-cabin position. It can be demonstrated during the training runs by comparing remote driver distance estimation to onboard measurements.		x	x

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-2F	[2]	The remote operators went through a steep learning curve and quickly familiarised with the remote control desk. For the majority of test subjects, 1-2 training runs lasting around 30 minutes were sufficient. Most of the participants were able to handle the tasks well. In addition, the test subjects already had experience of working with simulators and were able to adapt this experience to the remote desk	Relevant for training program design and the decision on how many training runs were required.			x
RT-2G	[2]	A maximum latency of 500ms should be aimed for images during the movement. A shorter latency is desirable but must not lead to unacceptably lower image quality. For the images of the surroundings for positioning when stationary, the latency can also be higher.	The remote driver should be made aware of the possibility of high latency affecting their driving performance. They should be trained on how to recognize and respond in case such situation occurs.		x	x
RT-2H	[2]	The remote operator must be able to always recognise a connection failure	The remote driver should be made aware of the possibility of high latency affecting their driving performance. They should be trained on how to recognize and respond in case such situation occurs.		x	x
RT-2I	[2]	The remote operator must be specifically instructed and trained in the technical and procedural aspects of "remote control". A concept must be developed for this purpose. This must also include the training of the other participants involved in the process (traffic controllers, shunting staff on trackside, staff for train preparation, etc.).	Very relevant for training. Topics to be addressed during pre-briefing, verbal instructions and training plans.	x	x	x
RT-2J	[2]	The remote operator should be able to take a break between two consecutive remote-controlled movements. This enables the remote operator to get along easier with the new situation.	Relevant for training program design		x	x
RT-3A	[3]	From a results-driven perspective, one can evaluate teleoperation through task success rate, completion time, and number of states completed during the task	Relevant for research program design of D38.2 (i.e. incorporation of specific tasks that can be evaluated). Not required for training.			
RT-3B	[3]	Remote driving performance can be measured using lane offset, task completion time, vehicle following distance, variation in following distance, emergency events reaction times, and speed variation	Relevant for research program design of D38.2 (i.e. incorporation of specific tasks that can be evaluated). Not required for training.			

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-3C	[3]	Industry experts found 6 categories of challenges for remote driving: · lack of physical sensing · human cognition and perception · video and communication quality, · remote interaction with humans, · impaired visibility · lack of sounds	Specifically not addressed during training, to observe the natural response of participants when driving remotely. This is part of the D38.2 human factors study.			
RT-3D	[3]	Safety challenges include loss of connectivity, stringent network requirements, risk of remote driving failures, lack of situational awareness for drivers, and deprivation of force feedback and acceleration.	Safety challenges must be mitigated in the operational plans and risk assessment. Drivers are trained on how to respond to network issues and difference of ROC perspective compared to onboard.		x	x
RT-3E	[3]	The report warns of detachment and loss of concern for the physicality of actions.	Specifically not addressed during training, to observe the natural response of participants when driving remotely.			
RT-3F	[3]	Compared to in-vehicle driving, 69% of participants stated that remote driving was more stressful. Several participants reported that they simply felt more aware. Commonly mentioned stressors are reported in Fig 2. Some other mentioned stressors were restricted field of vision, motion sickness and fatigue, poor weather conditions, sensor malfunction, distance/speed perception, unexpected traffic situations, vehicle agility, and decreased spatial awareness.	Specifically not addressed during training, to observe the natural response of participants when driving remotely.			
RT-3G	[3]	Some drivers felt they adapted to latency after 1-2 drives while others felt they adapted after 6 to 8 weeks or a couple of months.	Specifically not addressed during training, to observe the natural response of participants when driving remotely. This is part of the D38.2 human factors study.			
RT-3H	[3]	As for training structure, drivers mentioned that evasive manoeuvres and reaction time tests are important which can be measured with a safety driver in-vehicle.	Relevant for research program design of D38.2 (i.e. incorporation of specific tasks that can be evaluated). Not required for training.			
RT-3I	[3]	Remote operators should train communication protocols with any in vehicle safety driver to ensure clear, succinct communication in safety-critical moments.	Integrated into the verbal briefing of the training program.		x	x

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-3J	[3]	Drivers felt that local knowledge of the streets was essential to help them focus on the driving task and prepare for hazardous areas that might include increased road user presence, spotty network connections, or difficult intersections.	Specifically not addressed during training, to observe the natural response of participants when driving remotely. This is part of the D38.2 human factors study.			
RT-3K	[3]	The interviews highlighted that the training must include psychological aspects. One driver stated, "…it's really really important that you can drive and also can handle pressure and stress situations." Currently, it seems that remote driving training largely lacks psychological training both in the form of improving mental fortitude and in screening out those who may be at high risk for developing adverse psychological reactions.	Not included in the training program for this study considering the current TRL-level. Should be considered for future, longer, studies closer to implementation.			
RT-3L	[3]	Drivers felt that they always drove more defensively than they would in-vehicle.	Specifically not addressed during training, to observe the natural response of participants when driving remotely. This is part of the D38.2 human factors study.			
RT-4A	[4]	This document describes training for RD's that is divided into two main training area's:				
	[4]	1. Remote Driving specific training on the controllability of the solution, to familiarize the driver with specific functions and operating features of the system to develop an in-depth understanding of its technical capabilities and limitations.	To be incorporated in both the pre-briefing, the verbal briefing and practical training.	x	x	x
	[4]	2. The operational domain specific training is focused on the practical application of the solution within the target environment. This teaches drivers on the special characteristics of remote driving, such as coping with potentially weak network connectivity.	Will partially be applied during this training to cover scenario's that are applicable for the training environment. Not fully representative due to it being a research study instead of a full operational scenario.		x	x
RT-4B	[4]	In a period from August 01, 2023, to December 01, 2024, a total of 183 relevant disengagements were taken into account. Here, this work focuses exclusively on disengagements where the SD appropriately assumed control, such as in cases of errors made by the RD. The responsibility for these disengagements lies with the RD, whereby cases attributable to other traffic participant misbehavior or technical failures are excluded.	Relevant for research program design of D38.2 (i.e. incorporation of specific tasks that can be evaluated). Not required for training.			

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-4C	[4]	TABLE 2: Overview of remotely driven distance and remotely driven minutes by remote driving experience level.	Relevant for research program design of D38.2 (i.e. incorporation of specific tasks that can be evaluated). Not required for training.			
RT-4D	[4]	Especially in the first 400 km of driving experience, a strong decrease in safety driver interventions can be seen, which could indicate a rapid acquisition of skills or an improved comprehension of the remote driving system. From about 400–500 km the improvement in performance flattens out, so that additional experience only slightly reduces the number of interventions. This indicates that basic skills are developed at an early stage.	Relevant for research program design of D38.2 (i.e. incorporation of specific tasks that can be evaluated). Not required for training.			

The table within RT-4C Topic Content:

RD Level	Driving experience	Remotely driven distance	Remotely driven duration
RD–L1	<200 km	4132.56 km	13,202.53 min
RD–L2	200–500 km	5494.06 km	14,141.65 min
RD–L3	500–800 km	4665.04 km	11,510.48 min
All Levels	0–800 km	14,291.65 km	38,854.67 min

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-4E	[4]	 FIGURE 6: Count per disengagement reasons for different remote driving experience levels.	Relevant for research program design of D38.2 (i.e. incorporation of specific tasks that can be evaluated). Not required for training.			
RT-4F	[4]	According to the participants, the biggest challenge in remote driving is braking manoeuvres, which were described as challenging by 57.9% of the participants. Difficulties arise in particular from the limited haptic feedback and the perception of distance and speed.	Specifically not addressed during training, to observe the natural response of participants when driving remotely. This is part of the D38.2 human factors study.			

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-5A	[5]	The primary video stream shows the selected view from one of the cameras. The front perspective (normal zoom and enhanced zoom) can be switched to other views by using the video controls. The speed of the train limits the view of the pantograph and coupling camera, which are deactivated above 15km/h. The remote driver can influence what he sees, pending on the desired primary focus. The purpose is to highlight the focus to the remote operator.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x
RT-5B	[5]	The 2D map shows the real-time location of the vehicle selected in the ROC with surrounding tracks and objects. There is no interaction with the remote driver, it only provides additional information to the driver, for situational awareness. It currently does not display the direction of the selected cabin.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x
RT-5C	[5]	The secondary video stream shows the three video streams other than the one selected on the main video stream. All video streams currently show the outside view of the train, front perspective (normal zoom and enhanced zoom) as well as a pantograph and coupling focus camera. Note pantograph and couple camera will be shut down above a speed of 15 km/h.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x
RT-5D	[5]	The ETCS DMI shows information to the remote operator, identical to what is presented to the driver in the train. The information contains the train speed, ETCS level or current ATB code. Furthermore, it provides an indicator for an ATB brake intervention, an indicator that the brake criterium is satisfied and an indicator showing that ATB is not in service. Finally, this DMI will also be used to unlock ATB after a brake intervention occurred. The ETCS DMI is simulated using input of the CAF API, sounds and visual representation are not fully representative for the regular onboard DMI's.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-5E	[5]	The ATO DMI shows information to the remote driver, regarding the ATO system when driving under GoA2 conditions. The ATO DMI shows the following information: · ATO Status · The actual speed when driving ATO · Traction/brake percentages · Planning area based on the speed profile · Next stopping point, expected time of arrival and deviation of plan, stopping point location indicator and distance to next stopping point · Expected upcoming signal aspects (gmatrs + per) · Gmatrs signal aspect predictions and PER predicted upcoming signal · Current ATB code · Signal aspect correction option for driver In future it is expected that it will also show other information which is currently not available. A list of that information is listed here: · Slippery track indicator	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x
RT-5F	[5]	The control DMI is the visual interface of the ROC to be able to connect to the train remotely. After startup of the ROC, a login screen and vehicle selection screen are visible. When logged in, the train information is presented which is normally visible on the active cabin by means of physical buttons, lights, gauges. It shows the brake pipe pressure meter, brake cylinder pressure meter, the ABC malfunction indication lights and Deadman light.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-5G	[5]	The HMI is a representation of the train HMI, where the majority of the functionality is included. Not all is presented due to limitations on CAF side, i.e. the brake test is not included. It provides the remote operator with different types of information depending on which screen is selected in the train HMI. The screen active when driving, and also the most commonly used screen, is the "driver screen". This screen shows the rolling stock id, service id (ritnummer) and train clock (local time) in the header line. Next, it shows the active cabin and train set status. Finally, this screen also shows information regarding the brake/traction demand, battery/catenary voltage, operational mode, driving mode, main pipe pressure and total distance driven. Another commonly used screen is the "station screen" providing information regarding the door/ramp status, also shows the active cabin and provides a list of actual A/B/C category alarms.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x
RT-5H	[5]	The remote operation centre has the relevant train controls embedded within the desk. The purpose is to recreate the train cabin as good as is possible. This section will detail the most relevant controls for the ROC and will not describe all controls in detail.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
	[5]	<table><tr><td>**Number**</td><td>**Button**</td></tr><tr><td>1</td><td>ATO engage button</td></tr><tr><td>2</td><td>Camera view controls</td></tr><tr><td>3</td><td>Traction / Brake lever</td></tr><tr><td>4</td><td>Pantograph switch</td></tr><tr><td>5</td><td>Dead man switch</td></tr><tr><td>6</td><td>Cabin selection switch</td></tr><tr><td>7</td><td>DOM key</td></tr><tr><td>8</td><td>Signal correction keypad</td></tr><tr><td>9</td><td>Windshield wiper</td></tr><tr><td>10</td><td>Quick connector</td></tr><tr><td>11</td><td>Parking brake</td></tr><tr><td>12</td><td>Couple / uncouple</td></tr><tr><td>13</td><td>Typhoon</td></tr></table>	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
	[5]		Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	X	X	X
RT-5I	[5]	The camera view controls make it possible for the remote driver to switch between the primary and secondary video screens of the ROC.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x
RT-5J	[5]	The dead man switch is incorporated within the ROC desk, to the left-hand side, as a large black button. This solution was selected as the easiest in the current setup. There is not a specific reason to move the dead man switch pedal to the desk.	Technical solution to be elaborated on during pre-briefing and verbal instruction. To be experienced during training runs.	x	x	x
RT-6A	[6]	Training on elements that are **new** in the ROC, compared to the interface in the train. For this specific solution that includes camera usage, logging in.	To be included in the different training phases: Explain it during the theoretical briefing, show it during the verbal instruction and have the participants experience it during the training runs.	x	x	x
RT-6B	[6]	Training on elements that are **different** in the ROC, compared to the interface in the train. For example, the change in the point of view of the driver, network delays and user interfaces (i.e. button that is visualized on a screen, compared to a physical button).	To be included in the different training phases: Explain it during the theoretical briefing, show it during the verbal instruction and have the participants experience it during the training runs.	x	x	x

Relevant Theme ID	Source	Topic Content	Expert evaluation for training materials	Relevant for pre-briefing?	Relevant for verbal briefing?	Relevant for practical lessons?
RT-6C	[6]	Training on elements that are **missing** in the ROC, compared to onboard. For example, the lack of GSM-R, haptic/audio feedback or the option to perform brake tests.	To be included in the different training phases: Explain it during the theoretical briefing, show it during the verbal instruction and have the participants experience it during the training runs.	x	x	x
RT-6D	[6]	Training on scenario's that are handled **different** when operating remotely, or when operating in a test environment with a safety driver onboard. This includes how to manage loss-of-connection	To be included in the verbal briefing and have the participants experience it during the training runs.		x	x
RT-6E	[6]	SME's mention that the best way to get familiarized with remote driving is to gain hands-on experience of using the technology under supervision of an experienced user.	To be included as part of the practical training runs design.			x
RT-6F	[6]	The training should allow the driver to encounter all tasks that are necessary for their regular work. This could include tasks such as driving on a shunting yard or coupling/uncoupling but also specific "unhappy" scenarios such as encountering an unexpected obstacle such as a brake shoe.	To be included as part of the practical training runs design.			x
RT-6G	[6]	Some SMEs recommend including a theoretical training prior to the practical lessons.	To be included for the practical briefing.	x		
RT-6H	[6]	SMEs recommend including training elements that address the difference between the remote "experience" and the onboard "experience" of the drivers. Specifically, aspects such as distance/positioning estimations.	To be included in the verbal briefing and have the participants experience it during the training runs.		x	x

5.2. SURVEY ON THE TOPIC OF "REMOTE OPERATION"

1. What is your experience in relation to remote driving?

2. What topics should a new remote driver be thought prior to their first experience with remote driving?

3. How would you design the practical lessons for a remote driver? What topics should they encounter?

4. What did you perceive as most challenging when first getting familiarized with remote driving?

5.3. THEORETICAL BRIEFING FOR REMOTE DRIVERS

Disclaimer: This document was originally in Dutch which is the native language of the remote drivers involved in this study. It has been translated to English using generative AI, this translation was verified by the authors of this document.

Dear Train Driver,

Soon you will be participating in tests with remote shunting. In this letter, you will receive additional information about the tests that will take place and your participation in the study.

The tests will be conducted as part of a European research program, "Europe's Rail Joint Undertaking" (ERJU), in which NS participates. The goal of this program is for the rail industry to work together in order to remain competitive compared to the automotive and aviation industries. The purpose of the remote shunting tests is to see how this technology performs in an operational environment, what it can potentially deliver, and what challenges may arise. For the execution of these tests, NS receives funding from the EU.

(See also: https://vimeo.com/1069136994?share=copy)

Remote shunting will be carried out from the ROC in Utrecht. This is a replica of the control desk as it appears in the SNG:

This remote desk is directly connected to SNG trainset 3002, equipped by CAF with cameras and new software to enable remote command execution. From the ROC, as a train driver, you will operate this trainset and perform shunting movements between Hengelo and Enschede.

The tests are conducted without passengers and under the supervision of the Train Test Centre (TTC). There are always at least two test drivers from TTC physically present in the cab to guarantee safety. The train has a permit from the ILT to operate using this technology. Both TTC and this permit impose requirements regarding the safe execution of the tests.

Tests:

A test day is performed according to a pre-planned timetable by TTC. You will receive this timetable 2 working days before the test day. During the test day, operating takes place between Hengelo (station or adjacent sidings) and Enschede (station or shunting yard), always CBG. There is approximately 10 to 15 minutes rest between two test runs; the total test day lasts about 6 hours.

The structure of the test day is as follows:

- **Briefing:** First, a briefing takes place with extra explanation about the control desk and the test day setup.

- **Training Run:** You will carry out a few runs to gain experience with remote driving, specifically using the control desk. These take place under supervision.

- **Test Run:** During these runs, you will perform coupling or shunting movements while measurements are taken about your experiences and the execution of the run.

- **Special Procedures:** Depending on the test day, special procedures may be performed, such as combining/splitting, driving with dirty cameras, delayed connection, or operating with ATO.

During the tests, continuous voice and video communication is maintained with personnel on the train. The test driver is ultimately responsible for executing the tests and can intervene whenever necessary. All operational measures from TTC are described in the risk inventory, which you will receive together with the test timetable.

There may be some people present at the ROC for guidance, observations, or conducting measurements.

Driving from the ROC

Below is an overview of the control elements of the control desk; some controls differ from a regular trainset.

- **Traction / Braking:** The traction/brake lever on the control desk functions the same way as in the train.

- **GSM-R:** The GSM-R unit in the control desk is not in use (it communicates with the train controller of Utrecht, instead of the controller that is operating in the area of Enschede-Hengelo). All GSM-R communication is handled by the test driver.

- **Dead Man's Switch:** The dead man's switch works only via the hand button on the control desk.

- **Cameras:** There are four cameras on the trainset:
    o Front: Generic outside view.
    o Front + Zoom: A zoomed-in front view.
    o Coupling Camera: Shows the coupling and just in front of the train (only enabled under 15 km/h).
    o Pantograph Camera: Shows the pantograph (only enabled under 15 km/h).

You can switch which camera is displayed on the large screen using the 4 white buttons on the control desk.

There are also rotary knobs to adjust the brightness of the cameras, which can be used during sunset or at night.

- **DMIs:** The control desk includes screens for ATB, physical buttons/meters, and the HMI. These screens differ somewhat visually and auditorily from the train.

- **VGM:** It is not possible to remotely prepare the train for (major) departure; tasks such as brake tests and start of mission are performed by the TTC driver.

- **Map:** A 2D map is present to show the train's location.

- **Driving Direction:** The driving direction switch is used to select the cab to drive from.

- **Parking Brake, Coupling, Horn, Windscreen Wiper:** These buttons are present and functional.

Please note that delays in video or command connection can occur, image quality may deteriorate, or the connection may be lost completely. It is important always to communicate this to the research leader and test driver. If the connection is lost for longer than a few seconds, the train will automatically initiate an emergency brake.

Practical Matters:

The tests take place in the office building Laan van Puntenburg on the ground floor, behind the stairs near the main entrance. Prior to the test day, you will receive information on the exact test times and contact details of the research leader. The research leader can let you into LVP and the test room.

A few important points to keep in mind:

- These tests involve experimental technology and depend on many parties for successful implementation. It may happen that tests are cancelled or aborted at short notice.

- The ROC is considered a physical cab and falls under the same rules as regular train operation; therefore, it is imperative you are fully qualified as a driver and have knowledge of the material and route. We are regularly checked on this by ILT Inspectors.

- During the test runs, you will be asked several times to complete surveys or share your experiences. Some test days an eye tracker will be used, all done in consultation.

- On-site there is a coffee machine and refrigerator; the canteen can also be used to get lunch (Monday to Friday, 11:00-13:00).

More Information:

Previously, NS conducted similar tests in Groningen through a private collaboration with CAF, under the ATO program or Automatic Shunting title. More information about these tests can be found on iNSite or online:

- <Internal links of NS with more information on NS / Remote Driving>

If you have further questions, you can contact:

- <Redacted>

5.4. INFORMED CONSENT FORM

Disclaimer: This document was originally in Dutch which is the native language of the remote drivers involved in this study. It has been translated to English using generative AI, this translation was verified by the authors of this document.

Consent Form for Participation in the ERJU Remote Shunting Study with Eye Tracking and Surveys among NS Employees

Title of the Study: ERJU Remote Shunting

Principal Investigator: <Redacted>

Dear participant,

You are kindly requested to read and complete this consent form before participating in the ERJU remote shunting study being conducted. This consent form contains important information about the study, your rights as a participant, and how your data will be handled. Please take the time to carefully review this information and ask any questions before deciding to participate.

Why consent?

By signing this consent form, you give NS permission to process your personal data for the Human Factors Study involving surveys and Eye Tracking.

You may, of course, choose not to give your consent. Without your consent, personal data will not be collected. Refusal to consent will never have any negative consequences for you. Your choice not to consent will not be recorded or included in your personnel file.

Purpose of the study:

The purpose of the Human Factors study is to investigate how various factors influence the performance of NS employees in their working environment. We aim to gain insight into the human factors that may affect efficiency, productivity, and safety during task execution. The results of this study may contribute to improving working conditions and developing effective tools for NS employees.

The specific goal of this study is to gain insight into how a train driver experiences remotely controlling a train. These experiences will be used to better tailor the technology behind remote shunting to the driver's needs in the future. We will also share these experiences with European partners. Insights may be applied to future training materials.

Which personal data do we collect?

The personal data we collect for this study are as follows (the Data):

1. Prior to the start of the study and upon selection for participation, the following data will be collected:

- First and last name

- Job position

- Work e-mail address

- Work phone number

- Signature

- Whether your eyeglass prescription falls within the set of lenses provided for the eye tracker. The set consists of (single) lenses with diopter strengths between +3 and -5 in steps of 0.5 [yes/no]

- Eye condition (cataract/astigmatism/nystagmus) [yes/no]

- Experience with the technology under study [yes/no]

These personal data are necessary because characteristics like work experience may influence behaviour during the study. Your data on eyeglass prescription and eye conditions are collected to properly adjust the equipment.

Via the eye tracker, the following data will be collected:

- Voice audio

- Ambient noise including system noises from equipment (audio)

- Gaze direction (video)

- Pupil size

- Position of left and right eye

By signing this consent form, you agree that this personal data will be retained for the duration of the study for which it was collected. This means the data will be stored for a maximum period of one year.

Your personal data will not be shared with third parties nor transferred to countries and/or organizations outside the European Economic Area (EEA).

Risks and benefits:

Wearing the eye tracking glasses may cause mild discomfort, similar to wearing (sunglasses). This discomfort is generally minimal. The benefits of participation are that your input may contribute to improving working conditions, ergonomic design, and safe implementation of innovative workplace technologies.

Confidentiality and privacy:

All collected data, including eye tracking data, will be treated with strict confidentiality and anonymized as soon as the personal data have been collected. Your personal data will only be used for research purposes and will not be shared with third parties without your explicit consent. The data will be analysed at group level, and individual results will be reported anonymously.

Rights:

Under the GDPR, you have several rights. A complete overview of these rights and how to exercise them can be found in the Personnel Personal Data Privacy Regulation (see here – from page 10). If you wish to exercise any of your rights regarding the processing of your data, you can submit your request by emailing <Redacted>

You have the right to withdraw your consent for the use of your personal data (in whole or in part) at any time, without giving a reason and without any adverse consequences. Your supervisor will not be informed of this, and ending your participation will not affect your relationship with the project team or the researchers involved. You can do this by sending an email to <Redacted>

Consent and agreement:

By signing below, you confirm that you:

- Are 18 years or older;

- Are employed by NS;

- Have read and understood the information in this letter and have had sufficient time to ask questions;

- Your eyeglass prescription falls within the range of lenses provided for the eye tracker, which consists of (single) lenses with strengths between +3 and –5 diopters in steps of 0.5; and

- Do not have an eye condition.

You voluntarily agree to participate in the Human Factors Study with Eye Tracking as described above. More specifically, this means you consent to the processing of your personal data in accordance with this consent form and for the following purposes:

• Providing relevant demographic information such as age, gender, and experience level so that the study can be tailored to you. This information will be treated confidentially and used solely for research purposes.

• Wearing an eye tracking device during the Human Factors study. The device records your eye movements, such as fixations and saccades, to map attention processes. An audio recording will also be made. The device can be safely and comfortably worn like glasses according to the researcher's instructions.

• Participating in observation sessions where your work activities will be observed while eye tracking data are recorded. This may involve performing specific tasks, interacting with equipment, or communicating with colleagues.

• Participating in interviews, surveys or questionnaires where you are asked about your experiences, perceptions, and feedback regarding your work and work environment.

You understand that your participation is your personal choice and that you can decide to end your participation at any time.

Signature section:

5.5. GUIDELINE FOR VERBAL INSTRUCTION TRAINERS

Session Characteristics:

- Duration: 30 minutes
- Format: Semi-structured, interactive.
- Class size: one-on-one training.

Topic #1 Study Design:

Give the student an introduction on the design of the study and the expectations for the day. This should include the topics of:

- Day agenda
- Timetable overview
- Expected measurements
- Introduction of other attendees/researchers.
- Privacy & Data Protection.
- Purpose of the research.
- Funding of the research.

Topic #2 Technical Solution:

Give a general introduction on the technical solution and operating elements that are relevant for the students' first experience with remote driving. This should include:

- Camera's
    - Overview of camera's & position on the train.
    - Instruction on how to switch between camera views.
    - Limitations in camera field of view compared to onboard.
- User Interfaces
    - Comparison of user interfaces in ROC to onboard interfaces.
        - Buttons.
        - DMI's & user interfaces.
        - Alerts
        - Dead man switch
    - Explanation of missing features compared to onboard.
        - GSM-R voice communications.
        - Preparation/SoM
- New features
    - 2D Map

Topic #3 Operational Procedures

Provide an explanation on the operational procedures that are applicable during the tests. This includes both the happy flow and how to handle potential issues.

- Regular driving:
    - Communication guidelines with onboard safety driver, including announcing the signal aspect and intended actions.
    - Waiting / stopping points and potential disembarking of onboard personnel.
- Unhappy flow:
    - Procedure for network issues
        - Announce issues to safety driver
        - Brakes will automatically be applied by technical solution if latency exceeds 2 seconds.
        - Hand over control to safety driver in case issues persist.
    - Procedure for other operational issues:

- Safety driver will always intervene if deemed necessary. Further elaboration in the RI&E.

5.6. GUIDELINE FOR PRACTICAL INSTRUCTION TRAINERS

Session Characteristics:

- Duration: 3 runs + 10 minutes after each run.
- Format: Hands-on experience + active coaching.
- Class size: one-on-one training.

Topic #1 Static Testing:

When the ROC is online, but prior to the first departure the student can observe the interfaces and camera streams and gain first experience with non-driving related control elements.

- Camera Perspectives
- Camera selector buttons.
- Camera brightness buttons.
- DMI's & UIs.

Topic #2 Practical Runs:

Each student will have three training runs of approximately 10 minutes. During these runs, there will be increasing responsibilities for the driver:

Run 1: The remote driver will be driving, while constantly being coached by the trainer.

Run 2: The remote driver will be driving and is only being coached in case of issues.

Run 3: The remote driver will be driving, and the trainer will not mention any issues or observations, unless deemed necessary (i.e. safety concerns). The feedback will be written down by the instructor and passed to the student upon completion of the tests.

Coaching topics include:

- Usage of control elements (i.e. camera selection)
- Signal recognition
- Communication protocols
- Distance Estimation
- Degraded Modes
- RI&E Compliance

During the runs, the student will receive feedback from the test personnel onboard of the train related to the estimation of distances. They may be challenged with specific tasks, i.e. stopping alongside a reference location and receive feedback on their results.

REFERENCES

[1]   (NS) Van Zanten, J. & Goossens, N. (2024). *MMI Input for the RTO end report*. (v1.0)

[2]   (SBB) Rappo, B. & Napoli, S. (2025). *Final Report Proof of Concept – Remote Operation* (v1.1)

[3]   Hardin, B., Salvini, P., Jirotka, M., & Kunze, L. (2024, June). How Well Do Drivers Adapt to Remote Operation? Learning from Remote Drivers with On-Road Experience. In 2024 IEEE Intelligent Vehicles Symposium (IV) (pp. 23-28). IEEE.

[4]   Hans, O., & Adamy, J. (2025). Identification and Classification of Human Performance related Challenges during Remote Driving. arXiv preprint arXiv:2503.09865.

[5]   (NS) Windels, E & Zandstra, J (2024). *DESCRIPTION REMOTE OPERATIONS CENTRE* (v1.0)