Rail to Digital automated up to autonomous train operation

D41.2 – Testing reports & assessment

Results of the remote driving of tramways demonstrator.

Due date of deliverable: 29/11/2024

Actual submission date: 25/10/2024

Leader/Responsible of this Deliverable: Construcciones y Auxiliar de Ferrocarriles, S.A.

Reviewed: Y/N

Document status		
Revision	Date	Description
01	25/10/2024	First Issue
02	16/01/2025	Comments after external examiner assesment

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

Start date: 01/09/2023 Duration: 14 months

AcknowledgementS

This project has received funding from the Europe's Rail Joint Undertaking (ERJU) under the Grant Agreement no. 101102001. The JU receives support from the European Union's Horizon Europe research and innovation programme and the Europe's Rail JU members other than the Union.

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EXECUTIVE SUMMARY

The main objective of the WP41 is to implement a **REMOTE DRIVING AND TELECOMMAND** demonstrator up to TRL7. The WP41 works on the identification of use cases for the first demonstrator, development, implementation, and validation through a specific demonstrator in Oslo.

Particularly, this deliverable D41.2 represents the results of the activities foreseen under “Task 41.3 - Demonstration phase”, where scope is the first preliminary testing and calibration phase oriented to iterate and refine what developments will take place, followed by the official testing phase to reach TRL7.

After the demonstration phase reports with the results are to be produced. Then such reports are to be analysed to produce conclusions to be introduced in the iterative development process. Evaluation of KPI defined in Task 41.1 is also performed.

It is worht to mention that this task is based on the work performend in the WP40 where the basis for the operational use cases and the acceptance of the modifications and the neccesary approvals to carry out the demonstrator were obtained. In addition to this, also T41.1 and T41.2 have had a relevant impact as operational test cases and implemenation of the remote driving and telecomand demostration have been done.

This leads to the work gathered in this deliverable which key milestones are to check the conformity of the implementation carried out based on the work plan defined in the previous tasks. This led to show the compliance of the solution based on the test reports obtained and the conformity/non-conformity evaluation of each of the use cases, which have been grouped in three (Auxiliary circuit test, static functional test and dynamic functional test).

The demostrator also have been studied from the KPI point of view, which enhances the insisght of the solution for a broader perspective and not only the functional. In this case the results showed that the implementation of remote driving and telecommand for the analyzed use cases have an positive impact in more than one area such as operational productivity, safety and security improvements in working areas or availability and service quality improvement.

ABBREVIATIONS AND ACRONYMS

AV	Activity Safety Guard
CAF	Construcciones y Auxiliar de Ferrocarriles
CERES	CAF Remote Control Centre
DATO	Digital Automated up to autonomous Train Operation
DSD	Driver's Safety Device
IT	Information technology
KPI	Key Performance Indicators
MCB	Miniature Circuit Braker
PER	Perception system
R2DATO	Rail to Digital Automated up to autonomous Train Operation
SL18	Tramway type used in Olso and for demonstartor
STR	Sporveien Trikken AS
SW	Software
TRL	Technology Readiness Level
TC	Test Case
TD	Test Description
TV	Traffic Safety Guard

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1 INTRODUCTION

1.1 CONTEXT AND OBJECTIVES

Deliverable 41.2 **Testing reports & assessment** is an outcome of WP 41 **Remote Driving and Telecommand Demonstrator**. WP41 is part of the demonstrator cluster and urban light trains WP, aiming at selection and analysis of specific operational test cases and its development. The deliverable covers the methodology used during the test cases, the test case report and analyses the obtained results.

The reports are analysed from two different perspectives. On one hand, based on a conformity/disconformity wise to determine the correct implementation of the remote driving and telecommand[1] solution throughout the test cases. On the other hand analysing the impact of the solution by using Key Performance Indicators (KPI) defined in the D41.1 relevant to the system and operator point of view.

The deliverable describes main activities and results for the task 41.3 **Demonstration phase.** Modified SL18 tram of the Sporveien fleet in the CAF factory in Zaragoza with the new functionalities after being pre-tested in factory was transported to Sporveien Trikken depot at Holtet Oslo, which has been chosen for the demonstration phase due to its suitability.

The test cases for the demonstrator in Oslo have been carefully selected to evaluate the functional capabilities of remotely controlled trams and to demonstrate telecommand functionality at TRL7, as outlined in Work Package 41 (WP41).

These test cases are categorized into three main types:

- Auxiliary circuits tests
- Static functional tests
- Dynamic functional tests

Each category includes specific test cases that have been conducted following a systematically structured procedure. This methodology is also described in detail within this deliverable.

Upon completing all methodological steps, these activities resulted in a series of reports, each documenting the outcomes of individual test cases. The first step in the analysis was to determine compliance or non-compliance based on "OK/KO" results. This evaluation provides a measure of the successful development of the remote driving and telecommand system, aligned with the objectives of the use cases.

To further enrich the analysis, enhance understanding, and ensure the demonstrator's relevance for railway domain stakeholders, the report includes figures tied to the key indicators defined in D41.1. These indicators go beyond measuring implementation success; they also offer deeper insights into the solution’s functionality and its anticipated impact on broader deployment scenarios.

[1] Telecomand in this context is meant as data exchange without any active controll of the vehicle

1.2 DOCUMENT STRUCTURE

The deliverable D41.2 has been structured as follows:

- Chapter 1: Introduction (the current chapter).
- Chapter 2: Remote Driving Demonstration
    - Chapter 2.1: Testing strategy and test cases
    - Chapter 2.2: Test results
    - Chapter 2.3: Key Performance Indicators
- Chapter 3: Conclusions

2 REMOTE DRIVING DEMONSTRATION

2.1 TESTING STRATEGY AND TEST CASES

2.1.1 Testing methodology

A framework of action between CAF and Sporveien Trikken has been established, where the methodology for conducting all necessary tests for remote driving of tramways demonstrator is defined.

In this framework, different roles are involved during the test execution, testing document template and testing process steps are documented.

2.1.1.1 Roles

Different roles have been defined for Sporveien Trikken as the tram operator and for CAF as technical developer.

STR shall contribute to testing as agreed in the collaboration agreement and annexes and shall support CAF in validation of testing solutions.

STR Roles

i. Test Team Leader

This role will be responsible for:

- Ensuring that the test track is blocked/closed according to Trikkens operational procedures and secure the test area during the test.
- Ensuring that all the measures from test risk analysis and Trikkens operational procedures have been implemented before test execution.
- Ensuring that all test participants have good understanding of their roles, responsibilities, test procedure and test sequence.

Competence requirement for this role is either AV (activity safety guard, but acronym coming from Norwegian) or TV (traffic safety guard , but acronym coming from Norwegian). Tram driver certificate A will have this competence included.

ii. Remote Operator:

STR staff member allowed to:

- Start-up CERES station.
- Connect to the tram and identify incidences to be notified to the expert IT technician
- Execute remote static commands following STR procedures.
- Drive the tram remotely following STR and test procedures.
- Report incidences and provide a collaborative attitude to improve the solution.

- STR remote operator shall have licence A, B or C for SL18, have completed training for remote operations, fulfil all STR requirements for remote operations and shall have good enough English skills for communication with CAF personnel.

iii. Onboard driver:

STR staff member able to:

- Supervising the tram when a dynamic testing or static test is taking place.
- Stop the tram by the Safety mushroom based on its knowledge and experience, even training.
- Set the tram in a safe status according to the new functionalities.
- Report incidences and collaborative attitude to improve the solution.
- Onboard driver shall have licence A, B or C for SL18, have completed training for remote operations, fulfil all STR requirements for remote operations and shall have good enough English skills for communication with CAF personnel.

iv. Expert IT Technician:

STR staff able to assist with to:

- Identify and solve communication problems.
- Identify and report CERES incidences.
- Check locally SW versions, report errors, upload versions if needed.
- Download PER data (data form perception system) and data management.
- English speaker needed.

CAF Roles

v. Remote Operator:

CAF staff member allowed, under STR supervision, to:

- Start-up CERES station.
- Connect to the tram and identify incidences to be notified.
- Execute remote static commands following STR procedures.
- Drive the tram remotely following STR procedures.

vi. Technical Leader

CAF Staff member able to:

- Lead the test from the technical perspective.
- Establish acceptance criteria for the test carried out.

- Contact internally the appropriate expert of every single issue raised.
- Lead CAF team in this testing phase and ensure good collaboration with STR test lead for safe execution of tests.

2.1.1.2 Testing procedure

A testing procedure has been defined where all the necessary steps to carry out in a testing execution session are specified. Despite being a demonstrator, factors as the configuration management have been considered during the testing phase. In this sense, the procedure includes concepts as traceability, SW version management or test repository.

All the steps of the testing procedure are documented based on the "ALIVE Testing Description Template" defined in ANNEX 1.

Several testing sessions have been scheduled during the project. For each testing session, a Test Description document is created, where different topics and their corresponding battery of tests are defined.

The procedure consists of four main steps:

Step 1: DESCRIPTION

Fill out the description of the test, using the specific document "ALIVE Testing Description Template" defined in ANNEX 1, including at least the following information in Block 1:

- Title
- Technical Leader
- Subsystems involved.
- Brief description of the test and reference to a protocol if available.
- Unit or units with which the test will be conducted.
- Roles necessary for the completion of the test.
- Risk analysis of the test and proposed mitigation measures.
- Extra operational needs, if any, not derived from the risk analysis.
- Planning. Duration of the test.
- Configuration of the units before conducting the test.

Step 2: EXECUTION

The test will be executed according to the needs of the protocol.

Step 3: REPORTING

Once the leader of the test has gotten all the information required, they shall fill out Block 2 of the "ALIVE Testing Description Template" defined in ANNEX 1, including at least the following information:

- Updates over the initial Block 1 information.
- Brief description of the results obtained.
- Configuration of the units after conducting the test.
- Lessons learned, if applicable, for further protocols.
- Actions derived from this test for both partners.
- Feedback to risk assessments

The owner shall inform the other partner to receive their confirmation (Step 4). This information shall be submitted to the other partner sooner than three weeks after the end of the test.

Step 4: FILING

The owner shall file the completed Test Description (TD) in an agreed resource shared by both partners. If the report/s of the protocol/s included in the TD are interesting for the purpose of the project, they will be filed as annex of the TD.

2.1.2 Test cases specification

Test cases included in the protocols have been defined in table format including the following information:

- Test case identifier:

The Test Case ID (TCxx) is a unique number across the project. The test names are intended to give a brief and meaningful idea of the test objective and its context.

- Test objective:

List of the test conditions that this test case is verifying.

- Input data:

Description of necessary information.

- Test tools

Description of used programs or measuring systems.

- Preconditions

Described conditions that must be fulfilled before the Test Case is executed.

- Test execution

Defines the steps and sequence how the test is to be executed. This sequence of steps is to be numbered "1." to mark. If a further refinement of the step sequence is necessary, the step sequence can be supplemented by letters (e.g. "1a)".

- Expected Result

Describes the expected test result.

- Post condition

Post Condition to reestablish the Test Environment for the next test.

Table 1: Test case specification template

Test case			
Test Objective			
Input Data			
Test Tools			
Precondition			
Test Execution		**Expected Result**	**Result**
Post Condition			

2.1.2.1 Auxiliary Circuits Test

The following are the test cases covered in the static test procedure:

- Verification of driver's safety device in mode 0 – all installation for perception and remote control are switched off.
- Verification of driver's safety device in mode 1 – only installation for perception is switched on.
- Verification of driver's safety device in mode 1 – all installation for perception and remote control are switched on.
- Tram off - Remote wake up test.
- Remote control commands test.
- Remote driving loop test.
- Remote active cabin test.
- Remote driving commands test.
- MCB monitoring.

Note: Three different operational modes have been defined for the demonstrator unit.

- Mode 0: The unit operates without any modifications to the approved baseline configuration.

- Mode 1: The perception systems are activated while retaining the train control from Mode 0. In this mode, the unit is not equipped with any systems capable of taking actions on the vehicle.
- Mode 2: A new train control system is activated, enabling the execution of actions on the vehicle.

2.1.2.2 Static Functional Test

The following are the list of test cases covered in the static test procedure:

- TC010 - Start up the tram locally.
- TC020 - Start up CERES system.
- TC030 - CERES: Check connection status.
- TC040 - CERES: Connect to the tram.
- TC050 - CERES: View cab cameras.
- TC060 - CERES: Take remote control.
- TC070 - CERES: Show active cab camera.
- TC080 - CERES: Remote command – High Voltage connection.
- TC090 - CERES: Remote command – Bell.
- TC100 - CERES: Remote command – Horn.
- TC110 - CERES: Remote command – Hazard lights
- TC120 - CERES: Release remote control - active local cab.
- TC130 - CERES: DSD sequence test.
- TC140 - CERES: Lost communication between CERES and tram.
- TC150 - CERES: Restore communication between CERES and tram.
- TC160 - CERES: Turn off the tram prepared to be remotely turned on.
- TC170 - CERES: Turn on the tram remotely.
- TC180 - CERES: Turn off the tram but not prepared to be remotely turned on.

2.1.2.3 Dynamic Functional Test

The following are the list of test cases covered in the dynamic test procedure:

- TC010 – CERES: Local safety brake test.
- TC020 – CERES: Local emergency brake test.
- TC025 – CERES: Check of start interlock
- TC030 – CERES: Remote Emergency Brake test.
- TC040 – CERES: Drive the tram remotely up to 5 km/h.

- TC050 – CERES: Drive the tram remotely 100% and max speed is not exceeded.
- TC060 – CERES Remote Service brake test.
- TC070 – CERES: Communication lost between CERES and tram.
- TC080 – CERES: Remote DSD brake sequence.
- TC090 – CERES: Local driver brake priority over remote driver.

2.2 TESTING RESULTS

2.2.1 Testing results methodology

The test protocols have been executed and validated by testing engineers who are external from the project developer team.

A test report for each test protocol has been generated and stored in CAF database. In the report, the test results template is filled, which includes:

- Vehicle unit
- Test date
- Test place
- Environmental conditions
- Software versions
- Result of each test case
- Comments
- People involved in the test and their validation signatures.

As explained in D41.1 the tests have been split into three different protocols, *Auxiliary Circuits Test, Static Functional Tes*t and a *Dynamic Functional Test,* and intended to be executed in this order. First, *Auxiliary Circuits Test* to check the correct integration of the new systems and ensure that it does not have a negative impact on previously functions and sub-systems tested on the vehicle. Second, *Static Functional Tes*t to check the communication channel between CERES and the tram and execution of remote commands at standstill. Finally, *Dynamic Functional Test* to test video streaming quality in movement and remote commands to drive the tram.

As explained in section “2.1.1.2 Testing procedure”, in addition to the test report of the protocols also the results of the TD documents have been stored.

2.2.2 Testing report

All the test protocols have been passed successfully with all the test cases “ok”. To get this result, a cyclic process has been followed as not all tests were satisfactory at the first attempt. Different test sessions were conducted during the project, where improvements were verified getting the final solution validation.

The test reports with the results are stored in a common and controlled database shared among the work package partners, here are some examples of each of the protocols.

Auxiliary Circuits Test

CAF	TEST AND TRIALS PROTOCOL Auxiliary circuits Factory Type Test Procedure	sporveien
CAF.VH.P18.MD.001-GN -	SL18 AutoTram // R2DATO	Project Code: PPE- Q.68.92.276.04 Ed: A
Previous: CAF.VH.P15.MD.084-GN B		

SEC.	Nº	ACTION	EXPECTED RESULT	AL Nº	RESULT		COMMENTS
3	3.215	Deactivate cab C2					
3	3.220	*Bell*					
3	3.230	Simulate remote bell activation in C1. O1104_C1 =1	Bell active in C1.		✓	NA	
3	3.240	Simulate remote bell activation in C2. O1104_C2 =1	Bell active in C2.		NA	✓	

Figure 1: Auxiliary Cicuits test report example.

Static Functional Test

CAF	TEST AND TRIALS PROTOCOL STATIC FUNCTIONAL Factory Type Test Procedure	sporveien
CAF.VH.P18.MD.001-GN -	SL18 AutoTram // R2DATO	Project Code: PPE- Q.68.92.376.04 Ed: A
Previous: CAF.VH.P15.MD.084-GN B		

Post Condition	Horn is not active.

Table 11 – TC110 - CERES: Remote command – Hazard lights.

Test case	TC110 - CERES: Remote command – Hazard lights	
Test Objective	The objective of the test is to command the hazard lights remotely.	
Input Data		
Test Tools		
Precondition	The tram is switched on and in remote control and there is an active cab, and CERES system should be available	
Test Execution	Expected Result	Result
1. Request to switch on the hazard lights from CERES. 2. Request to switch off the hazard lights from CERES.	1. Hazard lights are switched on in C1, C2, S1 and S2. 2. Hazard lights are switched off in C1, C2, S1 and S2.	✓
Post Condition	Hazard lights are switched off.	

Figure 2: Static functional test report example.

Dynamic Functional Test

CAF	TEST AND TRIALS PROTOCOL DYNAMIC FUNCTIONAL Factory Type Test Procedure	sporveien	
CAF.VH.P18.MD.001-GN Previous: CAF.VH.P15.MD.084-GN	- B	SL18 AutoTram // R2DATO	Project Code: PPE- Q.68.92.376.06 Ed: B

Table 5 – TC040 – CERES: Drive the tram remotely up to 5 km/h.

Test case	TC040 – CERES: Drive the tram remotely up to 5 km/h	
Test Objective	The objective of the test is to validate the remote driving by applying traction. The tram should reach 5km/h speed and start braking.	
Input Data		
Test Tools		
Precondition	Tramway should be switched-on and in remote driving mode and CERES system should be available TC010, TC020, and TC030 must be passed.	
Test Execution	**Expected Result**	**Result**
1. Check tramway is in remote driving mode. 2. Select remote cab C1. 3. Press the acoustic signal before driving from CERES. 4. Release to disable the acoustic signal before driving from CERES. 5. DSD pushbutton sequence during operation 6. Request traction from CERES.	1. Tramway acoustic signal is played. 2. Tramway acoustic signal is stop. 3. Tramway starts moving and accelerating based on the requested traction demand. 4. The speed indicator is constantly shown in CERES screen and matches with the 5km/h speed limit, 5. Tramway moves without additional traction demand on coasting. 6. Tramway stops.	✓

Figure 3: Dynamic functional test report example.

2.3 KPI JUSTIFICATION

In section 3.3 of D41.1, a proposal for KPI evaluation in WP41 was outlined. However, during the period between the delivery of D41.1 and D41.2, a consensus on KPIs at the project level has been reached.

Therefore, it has been decided to include in this deliverable a chapter dedicated to KPI evaluation, both addressing the original proposal and assessing it from the project perspective.

2.3.1 Original approach

In order to evaluate the success and validity of the solution implemented during the project, it is crucial to assess the performance using defined Key Performance Indicators (KPIs). These KPIs are derived from two primary perspectives that reflect different aspects of the project's developments.

2.3.1.1 KPIs for Non-Innovative Developments:

This category focuses on go-no-go validation tests, where the primary aim is to assess if the integration of new components or technologies (such as equipment and electrical systems) has been executed successfully without affecting existing structures or systems. These types of developments are often considered less innovative but are fundamental to maintaining the project's baseline requirements. Their performance can be measured based on predefined protocols and benchmarks established early in the project.

Justification:

The non-innovative developments play a crucial role in ensuring that the new solution can coexist with existing systems without causing disruption or regression. It is essential to guarantee that all installations and integrations follow the technical standards to maintain system integrity and reliability. These KPIs are necessary for validating that the fundamental functionalities have not been compromised during the integration of new subsystems.

2.3.1.2 KPIs for Innovative Developments:

The innovative developments in this project aim not only to create but also to optimize the solution, ensuring it is both reliable and effective in practice. The evaluation of these developments is carried out through both qualitative and quantitative KPIs.

Qualitative KPIs: These KPIs are related to user satisfaction, system usability, and overall experience. They help assess the subjective success of the solution, especially from the perspective of those directly interacting with it, such as operators or users.

Quantitative KPIs: These KPIs focus on measurable factors such as system performance, resource consumption, and the tangible impacts on operations. This includes data-driven evaluations such as latency, system availability, and productivity benefits.

Justification:

For innovative developments, it is critical to not only deliver a functional solution but also ensure that the system is optimized and meets the project's broader goals of efficiency, reliability, and user satisfaction. By measuring both qualitative and quantitative indicators, the project can obtain a holistic view of how well the solution performs in real-world scenarios. These KPIs offer the framework to continually refine the solution as necessary, ensuring it reaches the desired level of maturity throughout its lifecycle.

2.3.1.3 KPI Results:

The following table outlines the KPIs initially defined for the project (part of D41.1). This list has been updated as the project progressed, and additional insights were gained. These KPIs have been applied to each test case and have provided a comprehensive framework for assessing the project's overall performance.

KPI	Type	Explanation	Measurement criteria
System integration without impact on existing vehicle	Technical	Evaluate if the protocols proposed for validating the installation in an existing vehicle and its non-regression are successful.	Yes / No
Solution quality for the remote operator	User Experience	Rating of the solution's quality for the remote operator	1...5
Image quality	Technical	Rating of the image quality	1...5
Image latency	Technical	Latency in milliseconds	ms
System availability	Technical	Failure rate	Failure rate
Productivity impact on operation (*)	Performance	Impact in %	+/- %

(*) This KPI has been reconsidered to ensure an acceptable level of measurement.

Each of these KPIs is analyzed below, justifying the work carried out, as well as a proposed indicator filled out by the end user, in this case, Sporveien Trikken as the tram operator or CAF as technical developer depending on each of them.

System Integration without Impact on Existing Vehicle: (Evaluator: STR)

This KPI ensures that any new equipment or software does not negatively affect the existing infrastructure. A binary pass/fail criterion is used to confirm whether integration has been successful without regressions focusing on different perspectives.

Definition	Measurement (YES/NO)
The new system has been integrated into the existing SL18 from both mechanical and electrical perspectives in an organized, differentiated, and easily recognizable manner for the maintainer.	YES
The system has been functionally integrated into the vehicle in such a way that the different modes of operation are clearly differentiated and segregated for proper operational use.	YES

Solution Quality for the Remote Operator: (Evaluator: STR)

This user experience KPI measures the usability and perceived quality of the solution from the perspective of the remote operator. A rating scale from 1 to 5 allows for an objective assessment.

It is important to highlight at this point that the goal is to reflect the quality of the solution from the perspective of a TRL7 demonstrator. Of course, there are improvements planned for the next phases to enhance this KPI in anticipation of the final product.

No major setbacks of the solution has been detected for user side and all comments and request could be considered as suggestions to further development and improvement of the tested solution.

Definition	Measurement (1…5)
Quality for the Remote Operator	4

Note: 1 too bad … 5 very good.

Image Quality: (Evaluator: STR)

As a technical KPI, the image quality directly impacts the effectiveness of the system for operators and end users. This KPI rates the clarity and resolution of the image, critical for proper functionality.

The previous comment regarding the KPI is equally valid in this case. The quality of the images obtained has been evaluated according to the demonstrator level that was aimed for. It is important to emphasize that for new use cases or different weather and lighting conditions, the goal is to improve the quality through technical enhancements.

Rating 4 for this KPI was influence by outstanding issues to be checked on user IT architecture side (firewall stups in the Sporveien internal IT architecture).

Definition	Measurement (1…5)
Image Quality	4

Note: 1 too bad … 5 very good.

Image Latency: (Evaluator: CAF)

Latency is a key technical performance metric that affects real-time operations. This KPI tracks the time delay in image transmission, measured in milliseconds. The measurement reflects the total time elapsed from the moment the onboard camera captures the image to when it is displayed on the remote operator's screen. This includes the time for capturing, processing, compression and decompression, transmission, reception, and other related processes.

CAF has implemented different configurations and used a variety of architectures that allow for varying performances in image latency. The current solution has been tested in continuous video streaming from Oslo to Berlin for fully functional remote driving.

Below is an image taken during the demonstrations at InnoTrans 2024. In the image, you can see two atomic clocks synchronized between Berlin and Oslo through the camera to measure latency, 360 ms in this case.

Figure 4: Glass to glass latency measurement

Definition	Measurement (ms)
Image latency glass to glass	340-380ms (Always under 400ms)

System Availability: (Evaluator: STR)

System reliability is measured by the failure rate. A low failure rate is essential for ensuring the solution can function continuously without interruptions.

The system is at a lower TRL (Technology Readiness Level) compared to a commercial product. However, test campaigns were conducted as part of InnoTrans 2024, during which six demonstrations were performed with approximately eight driving sessions per demonstration, without any availability issues being reported.

Definition	Measurement (%)
System availability	Failure rate close to 0%

Productivity impact on operation: (Evaluator: STR)

This KPI measures the solution's impact on operational productivity, focusing on improvements in efficiency rather than economic terms. It evaluates how the implementation enhances workflow, resource utilization, and overall system performance. The metric is expressed in percentage improvements, allowing for a clear understanding of productivity gains achieved through the solution.

KPI is related to depot operation and no evaluation for regular traffic in urban context is considered. Productivity evaluation is based on simple measurements of performed activities and compare with expected improvement base on experience for testing of remote control.

Definition	Measurement (%)
Productivity change for shunting	Estimated productivity improvement 10-15%[2]
Productivity change preparation of the vehicle for operations	Estimated productivity improvement 50-70%[3]
Productivity change for parking after operation	Estimated productivity improvement 10-15%[4]

2.3.2 R2DATO Approach

As part of R2DATO, a series of generic KPIs have been defined for all WPs within the Demonstration Cluster (from WP38 to WP46). Specifically, for WP41, it has been agreed to focus on two of them:

- Reaction Time
- Productivity.

The authors and contributors of this deliverable agree that the KPI "Productivity" has been adequately addressed in the previous section of this deliverable. Therefore, moving forward, the justification will focus on the KPI "Reaction Time."

2.3.2.1 Definition of Reduction Time in controlled areas:

This KPI evaluates the reduction in time needed to perform specific tram operations, including fleet management and preparation, start-up and shut-down procedures, maintenance tasks, and shunting movements. By measuring this time decrease, we can gauge the efficiency improvements achieved within the tram system.

The focus of this KPI is on quantifying time savings achieved through process optimizations, technology integration, or operational adjustments. It is expressed in percentage terms, comparing the current average operation time to the baseline time established before the implementation of improvements.

Justification

For this KPI there are included the following aspects:

Operational Efficiency: A reduction in operation time enhances the overall efficiency of the tram operations in depts and maintenance workshops, allowing for smoother and reliable usage. This contributes to better utilization of resources and improved service delivery.

Scalability of Operations: By analysing reduction times, operators can identify areas for further improvement and scalability, allowing for adjustments to service frequency or capacity based on demand.

[2] depending on level of automatization of pre-operational activities, estimate is still based on solution TRL7. Improve of productivity can vary depending on location – bigger improvement is expected in outdoor depot on Holtet than indoor depot on Grefsen.

[3] Idem.

[4] Idem.

There were three areas of consideration to evaluate reaction time reduction by using remote control of the vehicles.

Reaction time for preparation of the vehicles for operation – this covers all activities related to pre-operational control, systems startup, warming up unit to operational requirements (both cabin and passengers' area) and moving the vehicle to correct exit position for operations.

Shunting reaction time – this covers all movements within depot area, between parking and workshop, washing line, wheel lathe and back to parking area.

Reaction time for parking after operation – including parking position identification and parking vehicle in the correct position for subsequent operations (what is the next operation – washing, maintenance or ready for next day operation on selected line)

Definition	Measurement (%)
Reaction time change for the preparation of the vehicle for operations	Reaction time can be reduced by up to 50%
Change in reaction time in shunting operations	Holtet – 20% Grefsen 10%
Reaction time change for parking after operation	Holtet – 10% Grefsen 5%

3 CONCLUSIONS

Deliverable covers the test case reports and the KPIs assessment for demonstrator in WP41. Test cases are presented in D41.1[1] and are selected based on operational and technical suitability for demonstrating the remote driving solution for tramway following the operational rules in Oslo.

The results of the test cases provide the functional viability of the solution and covers the TRL7 agreed to be met in the grant agreement. The remote driving solution has been demonstrated in a real environment controlling the tram from Berlin to Oslo which indeed is a more challenging scenario as this kind of solutions are expected to be used in the surroundings of the depots or operational areas for which remote driving is selected.

The assessment of the KPI provides a view of the improvements this kind of solutions generates. These advantages are not only economic, but also in efficiency as proposed test cases can be handle easier. This efficiency will be clearer in a more scalable solution as number operations and trams under the control of the remote driving operation are greater and the remote drivers can handover from tram to tram faster reducing the time to be ready for the operation.

In this path, there is still room for improvement, and it is expected that related future steps, as the ones that will be carried out in the WP42, are going to enhance the current remote driving solution.

Short summary of the deliverable:

- Objective to validate the remote driving solution in a TRL7 is fully accomplished, test reports are used to assess the functional capabilities defined for remote driving.
- Key Performance Indicators selected for the understanding of the benefits of the solutions not only from the technical viability but from the operator's perspective show that remote driving is a feasible and important game changer.
- Next steps that are going to be taken in the direction of R2DATO WP42 are going to directly benefit and help to improve the remote driving solution making it closer to a final product.
- Further research and development of the solution is expected to continue in subsequent projects within FP2, where it will also be combined with use cases involving urban traffic environments.

REFERENCES

[1] D41.1 – Collection of test cases and validation criteria

ANNEX 1: ALIVE TESTING DESCRIPTION TEMPLATE

sporveien

SL18
AutoTram // R2DATO

-	30/04/2024	Issued for review	JANUS	RIBES	CELAYA
Revision / Status Code	**Issue Date** 30/04/2024	**Revision Description**	**Prep. Sign.**	**Chkd. Sign.**	**App. Sign.**

Supplier Logo: CAF	**SPV Review Code** 1 ☐ **Reviewed, no comments** 2 ☐ **Reviewed, with comments** Implement comments and submit 3 ☐ **Rejected. Implement comments and submit** 4 ☐ **For information only**
Supplier's Document Number: Q.68.92.051.01 -	
Contract Number: KON-00868	

Document Title:

ALIVE Testing Description Template

0. LIST OF REVISIONS

Rev.	Rev. Date	Chapter/Page	Description of change
-	30/04/2024		First Edition

The List of Revisions shall show solely the changes made for the current revision of this document.

All changes made for the current revision shall be described or referred to in this list and marked with a line on the right side.

Code	Q.68.92.051.01
Vehicle / Contract	SL18 R2DATO // ALIVE
Concept	ALIVE Testing Description

EDITION CONTROL

EDITION	REASON	DATE
-	First issue	30/04/2024

Prepared by: **Name**: Nacho Celaya **Date:** 30/04/2024	**Reviewed by:** **Name:** Dusan Patrik Klago **Date:** 30/04/2024

1. BLOCK 1

1. Title	
2. Technical Leader	
3. Test Type	Type 1; Type 2.1; Type 2.2; Type 2.3;
4. Test number/ reference	
5. Functionalities involved	
6. Description of the Test	
7. Units	SL18-455 ; SL18-456
8. STR Roles	

9. CAF Roles		
10. Risk Analysis	**Risk Description**	**Mitigation**
Risk 1		
Risk 2		
Risk .. n		
11. Operational needs		
12. Planning		
13. Configuration Management	**Equipment (Mode 2)**	**Initial SW version(s)**

Eq. 1		
Eq. 2		
Eq. .. n		

2. BLOCK 2

1. Updated info in Block 1	(Reference to the issue.)	
2. Description of the results (summary)		
3. Configuration Management	**Equipment (Mode 2)**	**Final SW version(s)**
Eq. 1		
Eq. 2		
Eq. .. n		

4. Lessons learnt	
5. ACTIONS	(To be notified)