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Rail to Digital automated up to autonomous train operation

D40.1 – Operational use cases collection

Selected operational use cases and functional analysis for demonstration.

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REPORT CONTRIBUTORS

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Daria Kuzmina	UITP	Selection of operational use cases, interface with other tramway operators in Europe
Nacho Celaya Vela	CAF	Selection of operational use cases for demonstrators and functional analysis for demonstration

EXECUTIVE SUMMARY

- Context and objectives:

  The selected high-level operational use cases and functional analysis for demonstration shall provide starting point for development, implementation, and validation of remote driving and autonomous movements functionalities through a specific demonstrator in Oslo.

  This selection of the high-level use cases covers scenarios for Remote Driving and Telecommand demonstrator in WP41 up to TRL7, and L4 Autonomous Movements demonstrator in WP42 up to TRL6.

  The deliverable provides up to date information about operational rules in Sporveien Trikken in Oslo. The operational rules are analysed and further transformed to operational use cases that are to be tested and validated under demonstrations in Olso.

  The selection is created by Sporveien Trikken and CAF with assistance from UITP. This deliverable gives a basis for modifications on the vehicles intended for demonstration. CAF is responsible for execution of demonstrator in Oslo.

  The list of high-level operational use cases is limited to demonstrator in the restricted non-commercial areas (demonstrators in WP41 and WP42) but also gives indication for high-level operational use cases for future demonstrator in and commercial areas. (Demonstrator in commercial areas is not part of the R2DATO scope).

  Even though the deliverable's main objective is to map high-level operational use cases at Sporveien Trikken in Oslo and demonstrations in Wp41 and WP42, UITP supplies interface to other tramway operators in Europe.

- Scientific/Technical approach or methodology:

  A startpoint for the work was to collect and review routines and procedures that are used to manage tramway operations in Oslo. These documents describe and all rules, requirements and prequisitions for tramway operations at Sporveien Trikken in Oslo.

  The set off operational rules was a basis for identification of high-level operational use cases considering operations as they are at the present time. The list was then updated with expected high-level operational use cases related to remote driving, telecommand* and autonomous movements (level 4 expecetd) in the restricted areas.

  The same methodology and approach was used for selection of high-level operational use cases for commercial traffic.

  The work has been performed from December 2022 to June 2023. Originally expected time for this work was too short (3 months until February 2023). This was not due to underestimating work needed and resources avaliable, but because of waiting for inputs from WP5.6 and WP6.6. These two tasks has not been ready to share input so soon in the project.

  Not receiving input from these WPs could cause a loss of valuable information. Deliverable has no interface to other WPs than WP40, WP41 and WP42. WP participants agreed on prolongation of the work and postponement of the delivery until 31.12.2023. Later delivery of the report does not impact the overall plan and quality of the project.

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

- Main (scientific) findings/conclusions from the deliverable:

  Findings and outcome from the work in this task give positive outlooks in regard that :

  - There is quite a large overlapping of opperational rules among many European tramway operators.
  - High-level operational use cases can be considered for validation of the technical solutions by others operators in Europe.
  - There exist technical solutions for remove driving and even autonomous movements already now for the most of the high-level operational use cases

- Deliverable status and further R&I is needed.

  The deliverable is finished in the boundaries of the scope set up for this task in grant agreement, however, there are many issues that may be further investigated and validated in the future projects of the Europe's Rail programme (and R2DATO "phase 2").

  Developement of new IT solutions and especially progress in AI can give a new possibility for HMI and all interfaces between perception and decision-making modules of the autonomous tram system in the future.

  The list of high-level operational use cases in commercial areas and mixed traffic is on rather high-level and needs to be detailed and elaborted further. This does not influence execution of the demonstrator planned in R2DATO scope.

ABBREVIATIONS AND ACRONYMS

ATO	Automatic Train Operation
CAF	Construcciones y Auxiliar de Ferrocarriles
CERES	CAF Remote Control Centere
COMMS	Communication
C1	Cabin 1 of the tram
C2	Cabin 2 of the tram
DATO	Digital Automated up to autonomous Train Operation
GNSS	Global Navigation Satellite System
HMI	Human Machine Interface
IPM	Incident Prevention Module
LOZ	Localization System
OR	Operation Rule
OCC	Operations controll center
R2DATO	Rail to Digital Automated up to autonomous Train Operation
PER	Perception System
SL18	Tramway type use in Olso and for demonstartor
STR	Sporveien Trikken AS
STILLVERK	OCC in Sporveien depots
T4	Level 4 – high driving automation
TCMS	Train Control and Monitoring System
TRL	Technology readiness level
UITP	International Association of Public Transport
UC	Use Case
V2X	Vehicle to (2) Everything

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2 INTRODUCTION

Deliverable 40.1 **'Operational use cases collection'** is part of WP 40 **'Autonomous Tram Demonstrator'** in the demonstrator cluster and urban light trains WP with the aim to identify the high level general operational use cases to be implemented in the demonstrator plan.

Deliverable contributes and has interface to the WP 41 **'Remote Driving and Telecommand Demonstrator'** and the WP 42 **Tramway autonomous movements in depot demonstrator**.

Two trams (model SL18 of the Sporveien fleet) are to be modified in the CAF factory in Zaragoza. Modified vehicles and new functionalities will be pre-tested in factory.

General high-level use cases descriptions, requirements analysis and allocation of the use cases is a part of the task scope, together with identification of functional requirements and their allocation to the subsystems integrated for demonstrator.

The selection and analysis of the specific operational use cases and their development to test cases, is to be demonstrated within the project scope.

TAURO project can be considered as a predecessor and some findings and information is taking into the consideration when selecting the high-level use cases. CAF, in the TAURO project, tested positioning systems for urban trains and perception sensors and modules. Part of the scope in the projects was also validation of additional sensors for vehicle location identification, perception functionalities, and shunting in the depot. Testing was executed in Zaragoza at Tranvia.

The scope of demonstrator for urban environment in WP41 and WP42 gives relevant premisses for content of this deliverable.

The use cases for the demonstrator in Oslo are carefully selected for demonstrating functionalities: remote tram control and telecommand up to TRL7 in WP 41 and autonomous movements (most probably level 4) up to TRL6.

The main contribution to this task within R2DATO is coming from WP 5.6 'Definition of urban light rail use cases and operational rules and from WP 6.6 'Specification of ATO functions for trams. There are also inputs from WP12 'Functional prototype development, testing and validation'. On the other side D40.3 contributes to WP41 and WP42.

The work started with collection and identification of the operational rules for non-commercial areas (depots and testing / closed tracks) at the demonstrator location in Sporveien Trikken in Oslo, Norway. This was a base for development of high level operational, technical and test cases.

Operational rules for non-commercial areas (an area within the tram network restricted to public access, primarily used for fleet maintenance and parking) regulates operations of the trams in regard to parking, stabling of the vehicles outside operations, pre-start control and verification of the vehicles before operation, all movements within defined areas – shunting, transfer to workshops, wheel lathe, washing line and parking again. The operational rules in Sporveien Trikken in Oslo consist of a set of procedures, regulations, routines, and requirements both for operations, vehicles, and staff. Based on the list of operational rules operational use cases were identified.

Operational use cases the first stage - only the state-of-the-art of operational rules representing how the Oslo trams are operated now - were examined and listed. This was done without considering the potential deployment of ATO. List of operational rules are on higher level and further elaboration and detailing shall be necessary especially in WP41.1 and WP42.1 (e.g., there are many signs and

signals that are described in operational rules, but it all sums up in operational use case “detect traffic sign or signal and take required action”).

Future operational use cases are taking starting point from the analysis of operation rules and existing operational use cases. They cover not only existing operational environment, but also possibilities and requirements originating from remote control / driving and autonomous movements of the trams in the non-commercial areas. The list represents a database of operational use cases that need to be matched with technical use cases.

Technical use cases are based on the requirements and expectations coming from operational use cases for remote driving and autonomous movements and are created in order to identify areas of possible deployment of automatization possibly also to be demonstrated in R2DATO. They include remote driving operations and vehicle control to autonomous movements of the test vehicles in non-commercial areas at Sporveien Trikken in Oslo).

Test cases are selected operational and technical use cases to be demonstrated along the project lifetime, which means validation and testing of technological solutions. The aim is to further design, modify, and integrate appropriated systems allowing development of autonomous driving functions.

The final product of this deliverable is a carefully selected list of high level general operational and technical use cases. This list is a start point for selecting of test cases to be validated during demonstrator. Use cases descriptions, requirements analysis, allocation, identification of technical and functional requirements are to be elaborate further in for example WP41.1.

It is obvious that not all operational use cases, as they are defined today, can be completely automatised with present technology limitations. However, it is important that tram operators are opened to changes in their operational rules and regulations, in order to find a compromise and come closer to fully driverless operations. This should be and is a long-term goal of this research and development.

Assumptions taken into consideration when selecting high level use cases for the demonstrator reflect:

- Limitations for operating the trams in restricted for public non-commercial areas.
- Safety and risk evaluation and analysis for the existing demonstrator locations.
- Technical limitations and technology development status at the time of the demonstrator’s tasks execution
- Limited possibility for automatization of some operational rules and use cases.
- Impact on improvement for operational and maintenance tasks in today’s operation environment.

For the demonstrator’s location has been chosen Sporveien Trikken’s depot at Holtet, Oslo (main demonstrator area with outdoor tracks suitable for testing) and Sporveien Trikken depot at Grefsen, Oslo (back up demonstrator area with indoor tracks suitable for testing).

3 REMOTE DRIVING DEMONSTRATION

3.1 DEMONSTRATOR LOCATION

3.1.1 Holtet depot

Holtet outdoor tracks is an important advantage of the testing and demonstrating of remote driving. Outdoors environment gives a possibility to test and validate equipment under various weather, light and external conditions. This is crucial for validating of the perception sensors and equipment.

Holtet depot is not occupied during the daytime more or less from 6 am to 6 pm and gives a possibility for multiple test scenarios and is equipped with advanced signalling system.

The location of the CERES, commercial name for the Remote Operating Centre developed by CAF under R2DATO, is also on Holtet in existing operation manager office. Office has good IT network and connections and real view to tracks dedicated to the demonstrator. A small workshop at the depot shall be used both for parking and minor repairs or installations.

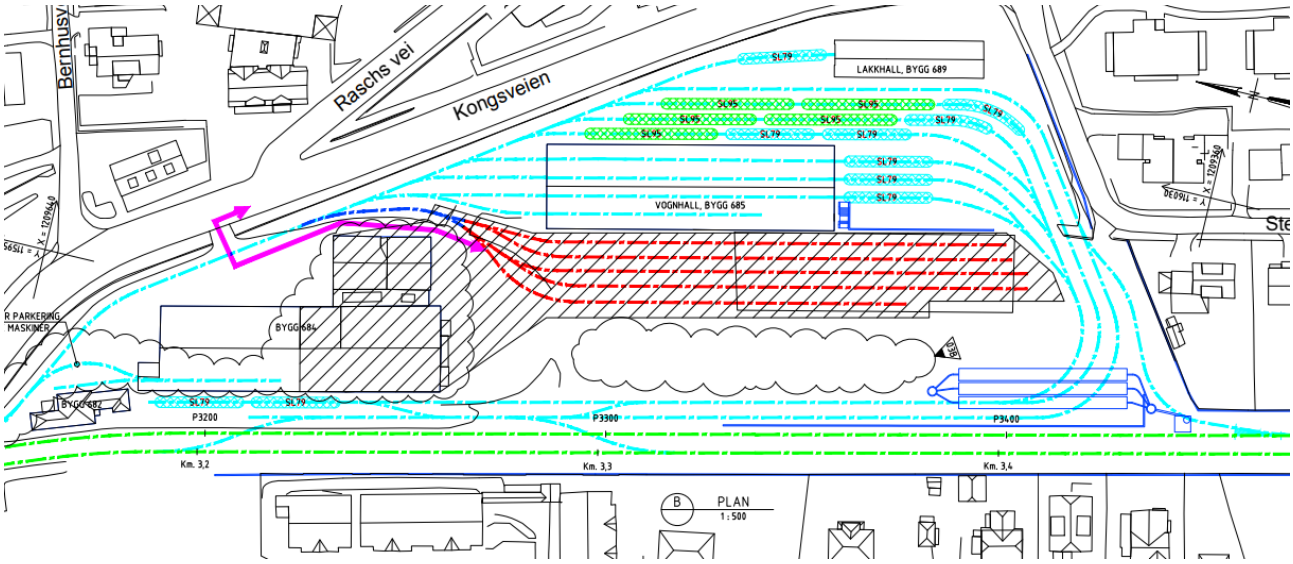

Figure 1: Tracks for demonstration (marked red)

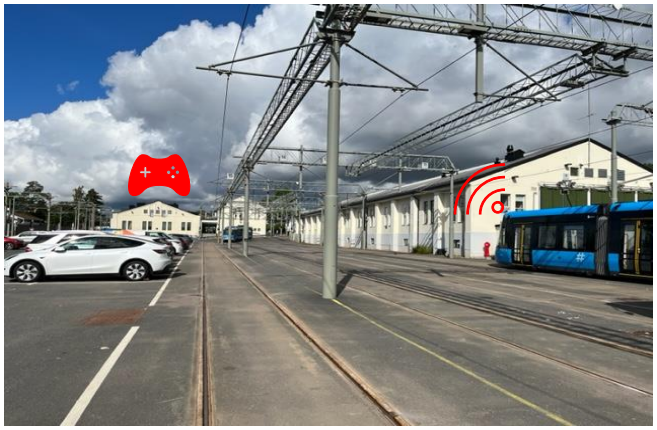

Figure 2: Tracks intended for demonstration

Figure 3: CERES for remote driving

3.2 DEMONSTRATOR HIGH LEVEL USE CASE SELECTION

3.2.1 ACTIVATING CERES

This high-level use case covers all operational and technical rules and the use case related to connection establishing activities.

Operational use cases covered: operations plan for the vehicle, selecting vehicle for operation, localization of the vehicle for operation, activating CERES.

Technical use cases covered: establish connection, initiate data communication, end connection.

Expected outcome: The connection with the selected tram existing in the depot is successfully established. Data communication has been initiated as expected. The connection with the selected tram is finished.

Actors: CERES operator

Functional description: The tram must be turned on, and the VPN connection available.

The remote operator may check on the HMI the whole fleet and identify, the status, the capability to receive a connection and if any of them is connected to CERES. Once the controller selects the tram it is not possible to connect to other tram from CERES and the data flows through the secured VPN.

After the operation the remote operator may disconnect the tram manually or the tram will disconnect automatically after a certain period of time.

3.2.2 START UP THE TRAM

This high-level use case covers all operational and technical rules and use case related pre-start checking and start up activities.

Operational use cases covered: check vehicle status, activate turnkey, service switch control, vehicle self-test, pantograph functionality control, control of alarms on TCMS-HMI monitors or alarm lamps on driver desk, “Deadman” button control, lighting both internal and external control, safety equipment control (extinguisher and first aid kit), check and report for any damages to the vehicle,

brake pre-driving control, pre-start control check out, connect to high voltage and position of the pantograph.

Technical use cases covered: perform video streaming, establishing connection with the tram switched on - remote control mode, switching on and off the tram prepared to be switched on remotely from the tram, switching off the tram prepared to be switched on remotely from the depot operation centre, switching off the tram not prepared to be switched on remotely, Switching on the tram remotely.

Expected outcome: Video streaming has been initiated as expected.

Actors: CERES operator, Stillverk – Sporveien' s depot operations centre, driver, shunting operator

Functional description:

Case 1: One tram within the depot has been switched off from the driver's cab and it finishes in "Tram Off Stand-By" mode. This mode implies that the tram is switched off, but a specific VPN secured connection device remain connected from the battery direct to receive a remote switch on command, so the tram may start up from the CERES command.

One tram within the depot has been selected from the OCC and it so the onboard PLC is inn "Remote Control" mode. This mode implies that the tram is switched on, and the OCC may send a list of commands and orders which do not implies any movement.

Case 2: One tram within the depot has been switched off from the OCC and it finishes in "Tram Off Stand-By" mode. This mode implies that the tram is switched off, but a specific VPN secured connection device remain connected from the battery direct to receive a remote switch on command, so the tram may start up from the CERES command.

Case 3: One tram within the depot has been switched off from the OCC and it finishes in "Tram Off" mode. This mode implies that the tram is switched off, and all devices remain disconnected so the tram may not start up remotely.

3.2.3 PRE-DRIVING ACTIVITES

This high-level use case covers all operational and technical rules and a use case related pre-driving activities.

Operational use cases covered: Check visibility and view all the cameras, verify the position of the vehicle, take control from C1, view the cameras from C1, leave control from C1, take control from C2, view the cameras from C2, leave control from C2, turn off the tram but prepared to be remotely turned on, turn on the tram remotely, execute telecommand not related to driving, put a pantograph into the required position.

Technical use cases covered: switching on the tram remotely, establishing remote driving mode, leaving remote driving mode on without losing connection to the tram, leaving remote driving mode on losing connection to the vehicle, changing the tram mode to a stabling mode, disconnecting the tram due to local cab activation, send remote commands to the tram, execute telecommand not related to driving.

Expected outcome:

One tram within the depot has been switched on from the OCC and in the end the tram may be remote controlled from the OCC.

One tram within the depot has been selected from the OCC and it finishes in “Remote Driving” mode. This mode implies that the tram is switched on, and the OCC may send a list of commands and orders which may imply movement.

One tram within the depot has been driven from the OCC and it finishes in “Remote Control” mode. This mode implies that the tram is switched on, and the OCC may send a list of commands and orders which do not implies any movement.

One tram within the depot has been driven from the OCC and OCC decides to disconnect the tram. The tram remains in “Stand-By” or “Battery Discharge” mode depending on the HV connection.

Actors: CERES operator, driver, shunting operator

Functional description: [Covered in Expected outcome]

3.2.4 REMOTE DRIVING

This high-level use case covers all operational and technical rules and use case related driving activities.

Operational use cases covered: Driving the vehicle in the restricted areas – non-commercial areas, check track for any obstacles before and during driving, acoustic signal before and during driving, identification of signals and signs during driving, acceleration, deceleration, braking to the standstill, sending, receiving and executing commands related to driving – lights on/off, using direction indicators, remotely controlling point machines, opening and closing doors, detecting other vehicles or traffic in front and around vehicle, identification of weather challenges, communication with signalling system, stop for parking.

Technical use cases covered: sending, receiving, and executing commands related to driving, accelerate, control driver activity, detect obstacle, decelerate, provide proper visibility, monitor cameras, acoustical warnings, manage external lights, select destination, Disconnecting the tram due to local active cab.

Expected outcome: The tram accepts the remote command and executes it, the tram accepts the acceleration demand and accelerates according to it (it starts moving or it increases speed), remote Driver activity detected by the tram and if no notification & braking sequence starts, an obstacle is detected, and tram applies the corresponding protection or alert, vehicle decelerates according to the command, wiper activated, washer activated, defroster activated check, acoustic warning emitted, dipped lights mode, main lights mode, lights off mode, flash main lights, and lights switched on, Emergency lights switched on, switch (point machine) changed according to the destination selected. Driver energizes the cab locally and overrides whatever remote command. Disconnection is forced.

Actors: CERES operator, driver, shunting operator

Functional description: Once the tram is connected remotely from CERES and the appropriated conditions are achieved, the tram is able to receive and execute remote commands even dynamic.

The CERES command is replicated in the tram in the same function level than the real coming from the local master controller, so this means that there are no functional changes in terms of programming. There exists several protections to check the quality of the service and the tram is protected from the onboard systems.

3.2.5 PARKING

This high-level use case covers all operational and technical rules and use case related turning oof the vehicle and parking activities.

Operational use cases covered: select parking plan and destination, drive to selected destination and stop for parking, set the vehicle in selected parking modus, put a pantograph into the required position, switch off communication to stand by or completely, terminate data communication, finish connection with the tram, secure vehicle from unauthorized driving.

Technical use case covered: changing the tram mode to stabling mode, end connection.

Expected outcome: the OCC manages to change the tram mode in one tram within the depot. After the mode selection the tram remain with no connection to the OCC. The connection with the selected tram is finished.

Actors: CERES operator, driver, shunting operator

Functional description: [Covered in Expected outcome]

4 CONCLUSIONS

Deliverable gives high level overview of the use cases, that shall be part of the demonstrator in Olso. Additional information in chapter 3 gives, however, also more detailed description of the operational and technical use cases, that are covered by these high-level complex use cases.

List gives good starting point for further preparation of test cases (part of the deliverable in WP41.1 and WP42.1) both for remotely controlled vehicle and autonomous movements in non-commercial areas.

Even though use case overview is based mainly on operation principles and operational rules form Sporveien in Oslo, high level approach opens possibility to apply them for others operator’s premises as well.

Deliverable is input to WP41 and WP42 with no direct dependencies towards other WPs in R2DATO, but methodology and approach has been synchronised with WP5.6.

It has been chosen 5 high level use cases:

- Activating CERES
- Start-up tram locally.
- Pre-driving activities
- Remote driving
- Parking

Information about what operational and technical use cases are covered by these high-level use cases, expected outcome and actors is also part of this deliverable.

REFERENCES

[1] D-D5.6 –Documentation of urban user cases and operational rules for automation process