

FP5TRAN S4M-R

Transforming
Europe's Rail Freight

D14.2

Test and Validation Report on DAC types

Project acronym:	FP5-TRANS4M-R
Starting date:	2023-01-01
Duration (in months):	54
Call (part) identifier:	HORIZON-ER-JU-2022-01 (Topic: HORIZON-ER-JU-2022-FA5-01)
Grant agreement no:	101102009
Due date of deliverable:	March 2026
Actual submission date:	2026-03-31
Responsible/Author:	Daniel Wolfram (DBC)
Dissemination level:	PU - Public
Deliverable Type:	R – Document, report
Doc Version & Status:	V1.0 Submitted

Reviewed: (Yes/No)



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"The project FP5-TRANS4M-R is supported by the Europe's Rail Joint Undertaking and its members."

Document history		
<i>Revision</i>	<i>Date</i>	<i>Description</i>
V0.1	22.02.2026	Version 0.1 – first creation
V0.2	17.03.2026	Version 0.2 - ready for review
V0.3	25.03.2026	Version 0.3 – review comments integrated
V1.0	31.03.2026	Version Final 1.0 – submitted

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Table of Contents

1	Executive Summary.....	6
2	Abbreviations & Acronyms	7
3	Background.....	8
3.1	FP5 TRANS4M-R Project and FDFTO Workstream.....	8
3.2	Test management process.....	9
3.3	Test instances, Quality Gates and TRLs.....	10
3.4	Information Process and User Expert Group	11
4	Objective/Aim.....	13
4.1	Task Description.....	13
4.1.1	Task 14.3 DAC Functional Train Laboratory tests	13
4.1.2	Scope of this Deliverable	13
4.1.3	Definition of Subtasks.....	14
5	State of the Art – TRANS4M-R DAC Testing	16
5.1	Introduction Train Test Lab.....	16
5.2	System under test – DAC types.....	19
6	DAC - Early Testing.....	23
6.1	System Integration.....	24
6.1.1	Goal of the system integration tests in WP14	24
6.1.2	Execution of system integration tests in WP14	25
6.1.3	Results of system integration tests in WP14	26
6.2	Test for E-coupler Assessment	27
6.2.1	Goal of e-coupler assessment tests in WP14.....	27
6.2.2	Execution of e-coupler assessment tests in WP14.....	28
6.2.3	Results of e-coupler assessment tests in WP14	28
6.3	DAC 2 Interoperability tests	29
6.3.1	Goal of DAC2 interoperability tests	29
6.3.2	Execution of DAC2 interoperability tests	29
6.3.3	Results of DAC2 interoperability tests.....	30
6.4	Additional early test examples	30

6.4.1	Armoured vehicle loading	30
6.4.2	Voith train separation and air valve venting capacity	31
6.4.3	Knorr-Bremse and Dellner actuator tests.....	31
7	DAC Validation Tests	32
7.1	Definition of Test Scenarios	32
7.2	Running Ability Test	33
7.2.1	Goal of the running ability tests	33
7.2.2	Execution of the running ability tests.....	34
7.2.3	Results of the running ability tests	34
7.3	Impact Tests	35
7.3.1	Goal of the impact tests	35
7.3.2	Execution of the impact tests.....	35
7.3.3	Results of the impact tests.....	36
8	Conclusions	37
9	References.....	38
10	Appendices.....	40

List of Figures

Figure 1	WP-structure in FP5 TRANS4M-R.	8
Figure 2	Test management within TRANS4M-R [DEL13.2].....	9
Figure 3	Test Instances and TRLs.....	10
Figure 4	Information flow and decision process.	12
Figure 5	Requirements for the Train Test Lab location	16
Figure 6	Train Test Lab in Berlin-Spandau	18
Figure 7	FP5 test locations for DAC tests	18
Figure 8	DAC overview and subcomponents.....	19
Figure 9	Evolution Dellner DAC.....	21
Figure 10	Evolution Knorr-Bremse DAC.	21
Figure 11	Evolution Voith DAC.	22
Figure 12	Wabtec DAC in 2025.....	22
Figure 13	System integration tests in TTL workshop	24
Figure 14	Draft gear installation steps.	24
Figure 15	Mobile testorkshop in TTL - demonstration of system integration.	25

Figure 16 Modification of T3000 installation space and system integration of special DAC from Voith.....	25
Figure 17 Hybrid DACs installed in TRAXX locomotive (Dellner: left side, Voith/Wabtec: right side).....	26
Figure 18 E-coupler concepts of Knorr-Bremse (left) and Voith (right).	27
Figure 19 DAC 2 interoperability tests.....	29
Figure 20 Examination of armoured vehicle loading with measurement system.....	30
Figure 21 Dellner actuator tests.	31
Figure 22 Test on ferry boat ramp.....	33
Figure 23 Coupling and decoupling in different infrastructure	33
Figure 24 Impact tests in TTL during winter 2025/2026	35

List of Tables

Table 1 Subtask within Task 14.3.....	15
Table 2 DAC evolution over project time.	20
Table 3 Extract of executed tests in WP14.....	23
Table 4 Relevant test cases and criteria for e-coupler assessment, assigned to WP14....	27
Table 5 Test cases for e-coupler assessment tests	28
Table 6 Infrastructure and assets for e-coupler assessment tests.....	28
Table 7 Infrastructure and assets for DAC2 interoperability tests	29
Table 8 Overview of test scenarios written within the WP14.	32
Table 9 Assets and Infrastructure for running ability tests	34

1 Executive Summary

This deliverable describes the work carried out under Task 14.3, “DAC Functional Train Laboratory Tests,” and summarizes the DAC-related vehicle-level tests conducted within a closed test environment (Train Test Lab). This document serves as a structured guide and refers to the detailed test reports in the appendix for each of the test campaigns that have been carried out. Chapter 10 provides an overview of the 17 attached documents.

Chapter 3 describes the system boundaries for the tests conducted here. WP14 is part of a test chain orchestrated by WP13, through which prototypes to be tested are transferred from one test instance to another according to their technology readiness level (TRL). In addition, tests can be divided into different phases based on their objectives. While the early testing phase focuses on the verification of requirements and early troubleshooting of prototypes, the task in the validation test phase is to test the prototypes according to their requirements and generate documentation for their use in demonstrator trains. The validation phase requires a coordinated approach and a communication structure. To ensure this, test scenarios with a detailed description of the planned test procedure were developed, and an escalation and approval process was defined through the User Expert Group (UEG) established in WP13. Following the definition of the objectives of this deliverable in Chapter 4, Chapter 5 provides an overview of the Train Test Lab, including the test sites and the DACs to be tested at various stages of development. The tests were largely conducted at the main site of HVLE in Berlin-Spandau. However, since some tests required specialized infrastructure, test campaigns were also carried out at the TÜV Süd site in Görlitz. From the start of the tests in mid-2023 until their completion in February 2026, suppliers Dellner, Faiveley/Wabtec, Knorr-Bremse, and Voith delivered DACs of various types and maturity levels. In addition to an expanded functionality, current DACs feature further significant improvements, for example in terms of derailment safety and installability. Chapter 6 describes the early tests conducted with the DAC as part of WP14. The tests for the e-coupler assessment carried out in early 2024 should be highlighted, as they played a key role in enabling a fact-based decision regarding the design selection of the e-coupler. In addition, the mechanical interoperability of a DAC 2 was demonstrated in a test campaign in mid-2024. Chapter 7 first describes the procedure for creating the test scenarios required for the validation tests. To this end, detailed test procedures were developed based on standards and test specifications. The test campaigns conducted within WP14 regarding running ability (EN 14363 and EN 16019), as well as the test campaign regarding the impact test (EN 15551), were able to demonstrate the general operational suitability and interoperability of actual DACs.

Keywords: Train Test Lab (TTL), Digital Automatic Coupler (DAC), interoperability, closed test environment, vehicle tests, validation, testing,

2 Abbreviations & Acronyms

Abbreviation / Acronym	Description
AAR	Association of American Railroads
BP	Brake Pipe
DAC	Digital automatic coupler
DBC	DB Cargo AG
DBST	DB Systemtechnik GmbH
DC	Dellner Couplers
DMS	Strain gauge (ger.: DehnungsMessStreifen)
e-coupler	Electrical coupler
eLCF	Endurable Longitudinal Compressive Forces
ERJU	Europe's Rail Joint Undertaking
FDFT	Full Digital Freight Train
FP5	Flagship Project 5 of the ERJU project
FT	Faively Transport - Wabtec
HBK	Hottinger Brüel & Kjaer GmbH
KB	Knorr-Bremse AG
LCF	Longitudinal Compressive Forces
oLCF	occurring Longitudinal Compressive Forces
P/F	Pass / Fail - criteria
ToR	Top of rail
TRL	Technology Readiness Level
TTL	Train Test Lab
VT	Voith GmbH & Co. KGaA
WP4	Working Package 4 of the FP5 – Authorisation requirements
WP13	Working Package 13 of the FP5 – Test management
WP14	Working Package 14 of the FP5 – Train Test Lab

3 Background

The present document constitutes the Deliverable D14.2 “Test and Validation Report on DAC types” in the framework of the Flagship Project FP5- TRANS4M-R as described in the EU-RAIL MAWP and contributes as well to the Flagship Project 101102009 - ERJU FP5 TRANS4M-R.

3.1 FP5 TRANS4M-R Project and FDFTO Workstream

The project aims to boost innovation for the European rail freight sector, concretely by developing, validating and demonstrating FP5 TRANS4M-R technical enablers, such as Digital Automatic Couplers and several digital train functions. The collaborative development of the various technical enablers is complex, which is why numerous work packages with different responsibilities were defined. The work in FP5 TRANS4M-R is divided into two main work streams as shown in Figure 1. The work stream highlighted in green on the right-hand side enables the processing of seamless freight operations. The work stream on the left-hand side focuses on the definition, development and testing of Full Digital Freight Train Operations.

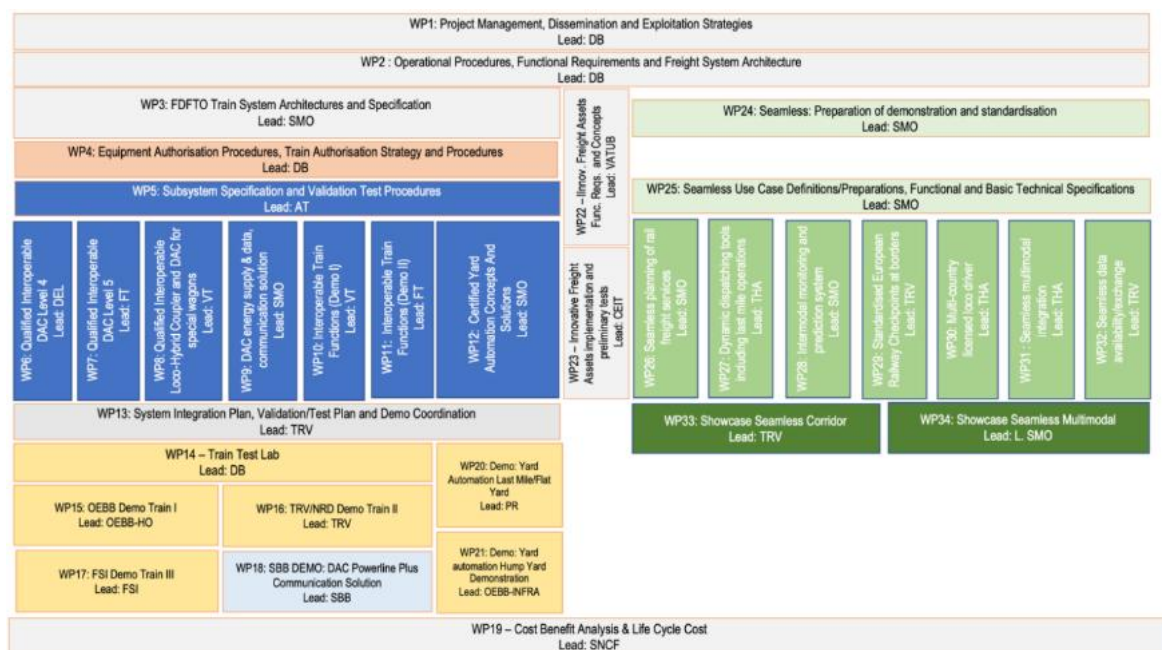


Figure 1 WP-structure in FP5 TRANS4M-R.

In work package (WP) 1, the entire project management is realised within FP5 TRANS4M-R. WP2 develops future operational processes and derives functional requirements from these, as well as a superordinate system architecture at train level. This is further detailed for the FDFT of WP3 for the vehicle system level, resulting in further requirements. WP4 uses the system architectures for RAMS analyses and is responsible for the authorization concept and the definition of associated requirements. The findings generated from these WPs are used to develop the detailed requirements for the individual subsystems or technical enablers in WP5. The design and development of prototypes for testing is then

implemented in WP6 to WP12 according to the associated subsystems. To test the subsystems or technical enablers, WP14 to 18, WP20 and WP21 were defined. These form a comprehensive test infrastructure, which is coordinated by WP13 and presented in detail in this deliverable.

3.2 Test management process

Within TRANS4M-R, all tests are coordinated by the test management system established in WP13. In accordance with DEL 13.1 and DEL 13.2 the main objective of WP13 is to coordinate all field tests to be carried out within FDFTO. To fulfil this objective, input from other WPs is essential. Figure 2 shows an overview of the most important interfaces. The individual WPs are clustered here according to their superordinate role in the V-model, outlined in EN 50126-1:2017.

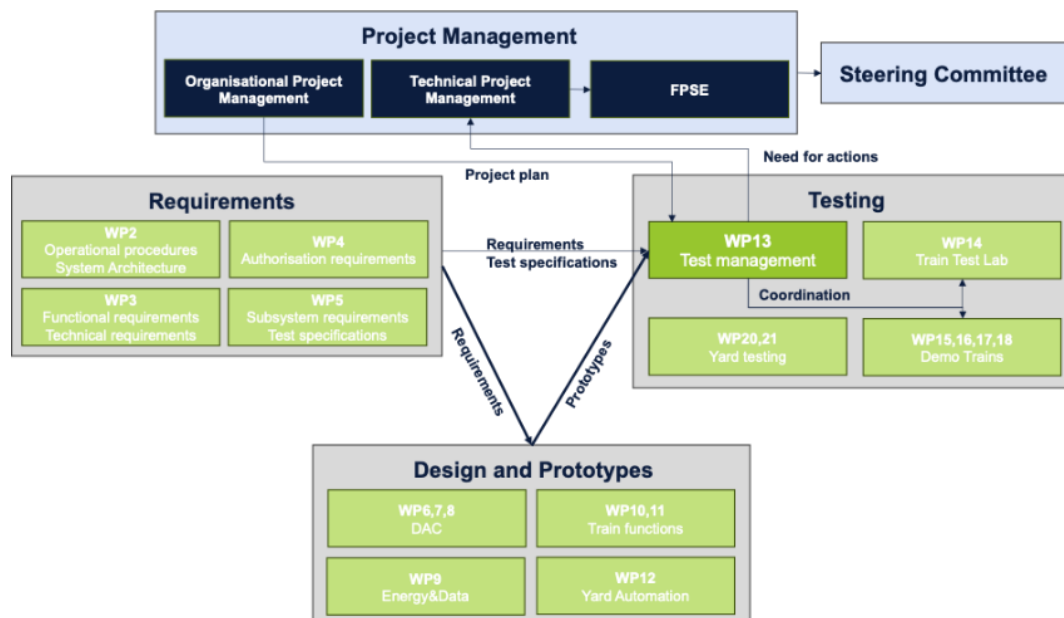


Figure 2 Test management within TRANS4M-R [DEL13.2].

WP2 to WP5 constitute the requirement cluster and are responsible for developing the requirements. Requirements include, for example, relevant limit values such as maximum forces, temperature ranges etc., which have a significant influence on a test setup. In addition to the requirements, test specifications are created by the same WPs. Based on definitions from WP3-10 designated industry partners will deliver prototypes of the technical enablers to WP13, which will then be distributed within the testing cluster. Delivery dates and the number of components must be aligned between WP13 and suppliers. Any changes to the plan shall be communicated and coordinated immediately.

One premise within the project is an **early test phase**. On one hand, this is intended to generate and verify requirements and confirm achievable limit values through a deeper understanding of the components and the application environment. On the other hand,

functional errors should be recognised as early as possible. As this results in different prototype variants, a description of the functionalities of each component is required. This should include the supplier's expectations as to which requirements are to be fulfilled by the prototype and which tests are to be carried out.

The primary objective of the early testing phase is to verify and then freeze product requirements, thereby enabling the production of prototypes that are as close to the final product as possible. Toward the end of the project, these prototypes are to be verified and validated in accordance with ISO 9001 (V-Model) during the **validation test phase**.

3.3 Test instances, Quality Gates and TRLs

To always ensure safety, particularly during the early test phase, various test instances have been defined (see Figure 3). Prototypes are first pre-tested on test rigs. If the prototypes tested there meet the requirements summarized in Quality Gate 1, they can be transferred to the next test instance, the Train Test Lab. There, the components are installed in vehicles for the first time. This means that, in addition to component-level testing, vehicle-level testing is possible here for the first time. The Train Test Lab's task is to test components in vehicles in accordance with the requirements specified in Quality Gate 2, thereby enabling their use in demonstrator trains. Demonstrator trains are test trains supervised by qualified personnel and often equipped with specialized measurement technology. The goal is to test for requirements described in Quality Gate 3, by testing operational suitability, use cases, and interoperability with respect to various infrastructure types. A successful Quality Gate 3 should enable the operation of commercial trains, which are to be implemented in follow-up projects, particularly after the successful completion of TRANS4M-R. These are operated primarily by regular staff and deployed in commercial service with real loading and unloading processes in collaboration with selected customers.

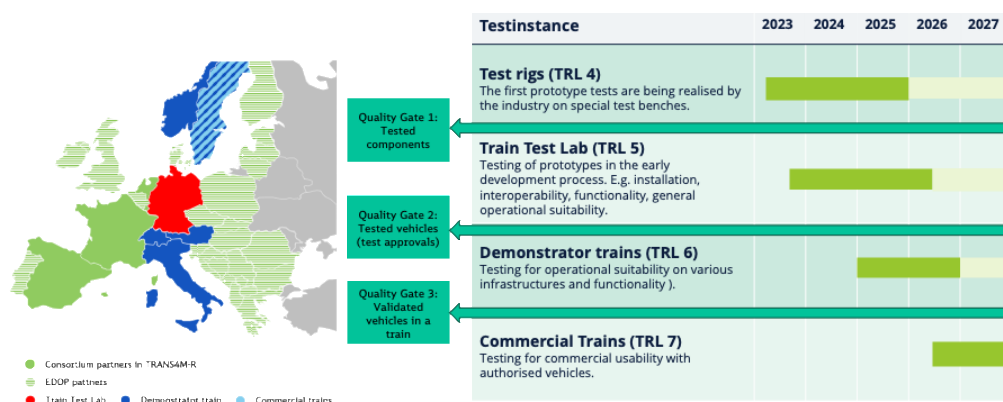


Figure 3 Test Instances and TRLs.

The TTL managed in WP14 operates primarily at locations within Germany. Demonstrator trains are scheduled to run primarily in Austria and Italy, but also in Switzerland. In Sweden and Norway, test trains are being used in commercial operations. The test program is thus capable of demonstrating the suitability of products up to Technical Readiness Level 8, the Europe-wide rollout, and the migration from the screw coupling system to the Full Digital Freight Train (FDFT). However, the primary objective is to conduct a detailed verification assessment for TRL 7, particularly to enable the CEF-funded “PioDAC trains” project. In some European partner countries, vehicles equipped with certified components additionally require authorization for use. Therefore, tests must be specified to the appropriate quality standards and be carried out. This includes the monitoring of the tests by certified testing facilities and the use of specialized measurement technology. The preparation and implementation of such validation tests within WP14 are described in chapter 7.1.

3.4 Information Process and User Expert Group

Particularly for the validation phase, responsibilities, information flows, and decision-making processes must be clearly defined and coordinated within the TRANS4M-R project. To this end, the information workflow shown in Figure 4 was approved in collaboration with WP13. Product requirements within TRANS4M-R are documented in a requirements management tool called Polarion. Additionally, WP5 is responsible for creating test specifications. Within WP13, further information - such as specific requirements for prototypes to be tested, as well as general requirements for the vehicles and measurement technology to be used - is developed in so-called test cases. The documents are then handed over to the relevant test work packages. These supplement the information from the test specifications and test cases with additional necessary definitions, such as exact individual tests and procedures, as well as specific measurement technology and the utilization of individual vehicles and infrastructure. All this information, along with a time and cost estimate, is submitted to WP13 for approval.

Once the test scenarios have been approved, execution of the tests begin. This process yields not only measurement data but also corresponding test reports. To assess whether individual results from specific suppliers are suitable for use in demonstrator trains, the so-called User Expert Group (UEG) was established in WP13. In addition to technical experts, this group consists of safety officers from the demonstrator trains to be built within TRANS4M-R. Due to confidentiality agreements, the supplier-specific test results are therefore accessible only to the suppliers themselves and the UEG. Within TRANS4M-R, the presentation of detailed supplier-specific results does therefore not take place. However, the test results are presented and discussed in general terms for the respective products. The UEG is also responsible for verifying proper execution of tests through the

test work packages, as well as escalating incorrect execution or negative test results to project management.

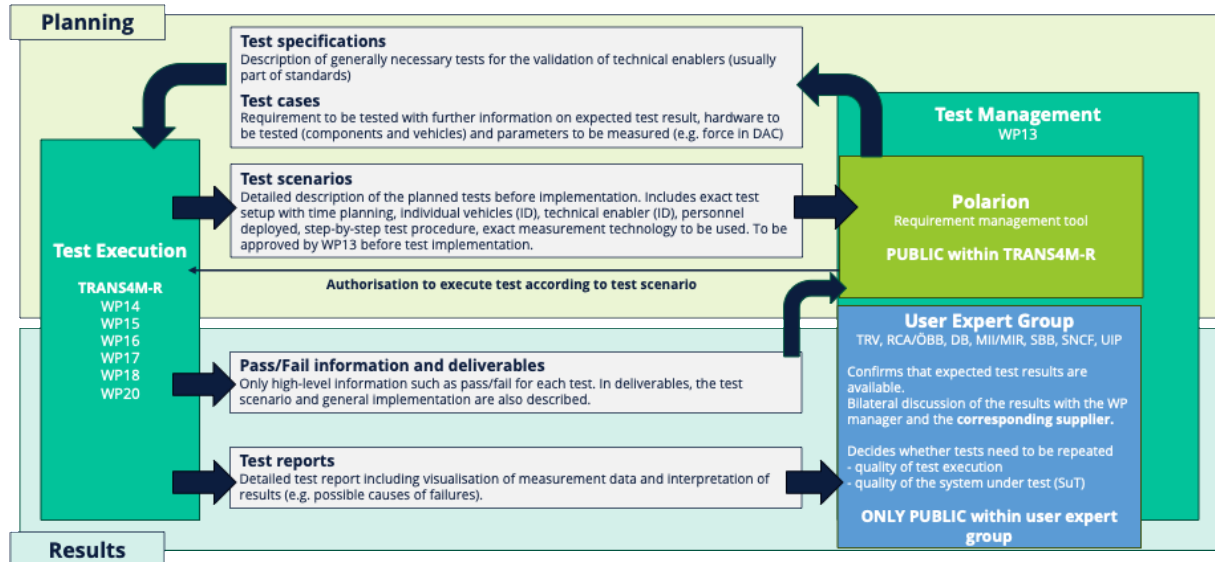


Figure 4 Information flow and decision process.

It should be emphasized once again at this point that this deliverable will not disclose detailed supplier-specific results. However, in addition to a detailed description of the planning and implementation process, the general results of each test campaign will be described and evaluated in relation to the product (in the case of this deliverable, regarding the Digital Automatic Coupler - DAC). The full test reports with all confidential information included can be requested at the respective suppliers.

4 Objective/Aim

The objective of WP14 – “Train Test Lab” (TTL) is to enable and execute the validation of the FDFTO requirements in a centralized FDFTO lab and in a harmonized way. The aim is to establish a joint, one-of-its-kind environment for the project and the railway freight sector to move up across the envisaged TRLs in a cost-efficient and effective way. Test procedures of the technical enablers, both on component/subsystem and on train level, according to the developed validation and test plan shall be possible. By using the train test lab specific operational procedures can be pre-tested, and on the other hand retrofitting efficiency, maintainability and serviceability assessments can be analyzed. Also, developer tests will be carried out to ensure the suitable system-approaches for the FDFTO-energy- and communication system for locomotives and wagons. Reference test systems for testing the functional interoperability of the developed technologies will be provided and established. Certification bodies can inspect components and equipped assets in the Train Test Lab and plan and coordinate the steps for approval together with the project partners.

4.1 Task Description

The DEL14.2 “DAC Functional Train Laboratory tests” is a summary of the work within Task 14.3 “DAC Functional Train Laboratory tests”. The purpose of this chapter is to provide an overview of the subtasks and the corresponding structure of the deliverable. Task 14.3 is described as follows in the TRANS4M-R Grant Agreement [GA].

4.1.1 Task 14.3 DAC Functional Train Laboratory tests

- Lead: KB
- Participants: KBHU, DB, DBC, DBSYS, SMO, DEL, VOI, FTI, FTAMS, OEBB-RCA, OEBB PR, OEBB TS, UIP, THA, NRD, FRET SNCF, R4L, SNCF-VOY
- Start: M13; End: M45

According to the tests outlined in Task 5.1 to 5.3 the interoperability of different DAC types shall be tested. The testing will be performed in a round robin. At least two different partners solutions have to successfully demonstrate interoperability at every functional DAC level. The ambition is though that all (DEL, KB, KBHU, VOI and FTI) will demonstrate interoperability. Once full interoperability is shown the DAC supplier is expected to have the basic documentation needed for the input for the authorisation of wagons. In addition, tests focusing on display and control elements will verify usability in an operational environment. The results will be evaluated and conclusions for each DAC type will be documented. [GA-TRANS4M-R]

4.1.2 Scope of this Deliverable

The focus of the work within the described task is on testing Digital Automatic Couplers (DACs) in a closed test environment on vehicle level. Tests of other automation

components in the TTL, such as power and data systems or train functions, are addressed in Task 14.4 and described in DEL 14.3. This also includes tests of uncoupling via a DAC's data line, for example, using an HMI in the locomotive. These tests focus on the entire digital control chain for uncoupling. However, the analysis of the mechanical uncoupling process, including the use of actuators, is also part of this deliverable.

As the project progressed, it became clear that extensive vehicle testing was required, which was not included in the originally planned scope of WP14. This includes tests regarding derailment safety, climate chamber tests on a vehicle level, and crash tests. WP 1 of the ERJU - FP5 - DACtiVate project is responsible for conducting and evaluating these tests. The work is described in DEL1.1 and DEL1.2. Furthermore, the installability and maintainability of DACs are only briefly described in this deliverable. A detailed analysis of this topic was carried out in Task 14.5 and described in DEL 14.5 and DEL 14.6.

Also, only the tests conducted in the closed test environment (TTL) are described. Results from DAC bench tests are generated in WP6, WP7, or WP8 and presented in the corresponding deliverables. Results from tests on demonstrator trains are the responsibility of WP15, WP16, WP17, and WP18 and will also be published in separate deliverables. A summary of all test results will be compiled in WP13 in DEL 13.3 and DEL 13.4 and published at the end of the project.

In addition to conducting the tests, numerous preparatory and follow-up activities are required. These include, for example, setting up test locations, selecting and equipping test vehicles, selecting and engaging subcontractors, as well as defining and implementing the necessary management processes. This work was carried out in Task 14.1 and is not described further in this deliverable.

4.1.3 Definition of Subtasks

In general, the tests can first be categorized based on their test phases. Following an introduction to the Train Test Lab in Chapter 5, Chapter 6 presents the early tests. This is followed by the validation tests in Chapter 7. Various test campaigns were carried out within each phase. These differ primarily in terms of their specific test objectives and, consequently, also in the infrastructure and measurement technology required for the tests. Table 1 provides an overview of the completed subtasks, which also serve as the basis for the further structure of this deliverable.

Table 1 Subtask within Task 14.3

	Task definition from GA (Task 14.3)	Output of deliverable
Subtask 14.3.1	Early tests Supporting the development process by fast and flexible testing of new prototypes and quick feedback to industry. Verification of requirements and support for design decisions as well as selection of operating principles.	Presentation of selected early tests in Chapter 0. The most important test campaigns were the e-coupler assessment (Section 0) and the DAC 2 interoperability tests (Section 6.3)
Subtask 14.3.2.1	Validation tests Validating DAC regarding requirements. Proof of interoperability and functionality. High quality of test execution together with certified test institute.	Description of validation tests in Chapter 0. Test campaigns within WP14 included running ability tests (Section 7.2) and impact tests (Section 0)

As described in section 4.1 of the task description, the main objective is to demonstrate interoperability between vehicles equipped with prototypes from different suppliers. This was achieved during the tests by consistently testing all supplier combinations. In addition, analyzing the DAC's operating capabilities (exception decoupling via HMI—part of DEL 14.3) is another objective in all test campaigns.

5 State of the Art – TRANS4M-R DAC Testing

This chapter presents key factors of the tests described in this document. Section 5.1 will discuss the test locations, with a particular focus on the main site of the Train Test Lab in Berlin-Spandau. Section 5.2 will then provide an overview of the system under test: the digital automatic coupler in its various functional configurations.

5.1 Introduction Train Test Lab

Right from the start of the TRANS4M-R project, it became clear that a location was needed for early testing of prototypes in a closed, safe test environment. As part of Task 14.1, requirements for such a location were therefore defined, and suitable sites in Europe were identified for implementation. Figure 5 provides an overview.

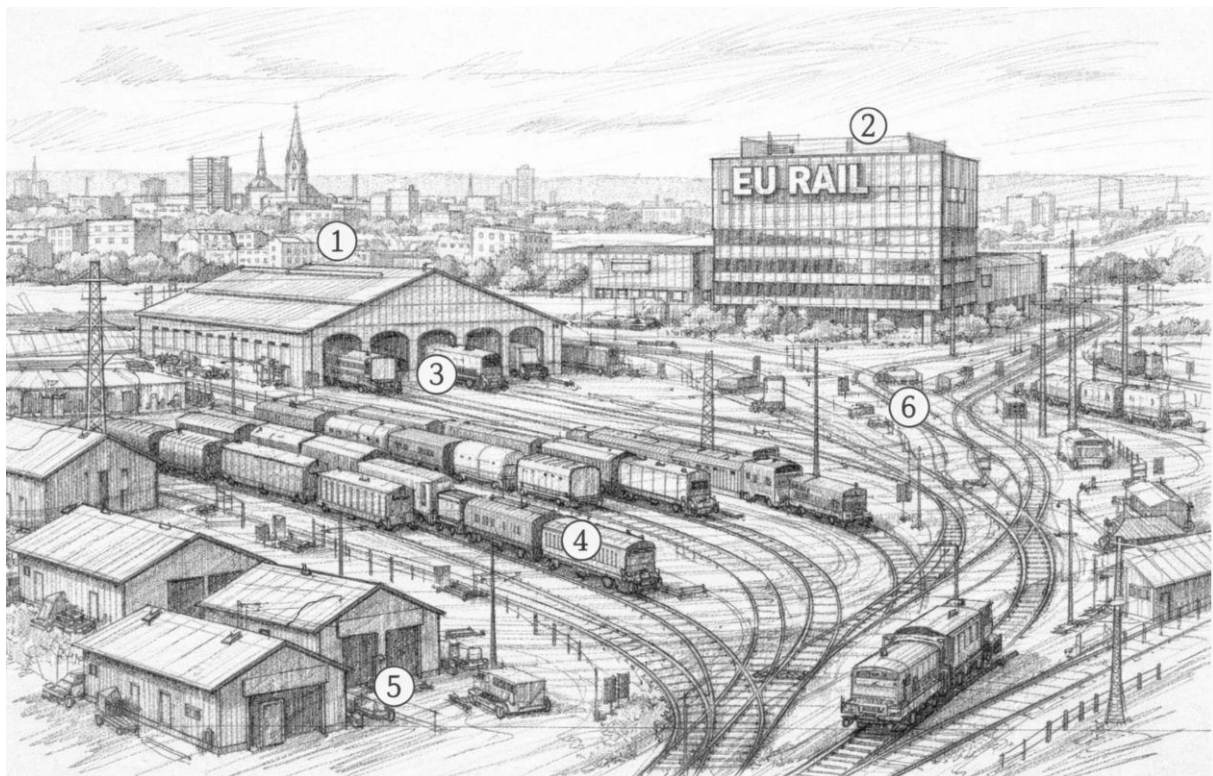


Figure 5 Requirements for the Train Test Lab location

- 1) The Train Test Lab should be reachable and easily accessible to TRANS4M-R project stakeholders.
- 2) The Train Test Lab shall provide staff lounges and work areas for TRANS4M-R staff.
- 3) Workshops are provided in the Train Test Lab for the installation of technical components in freight wagons and locomotives
- 4) Train Test Lab provides parking and shunting for the modified test vehicles.
- 5) The Train Test Lab has sufficient storage space to store components and equipment and is able to execute necessary logistics processes.

- 6) Within the Train Test Lab, necessary tests for the suitability of technical components with regard to their operational capability can be implemented on the corresponding infrastructure.

In the Train Test Lab, freight wagons and locomotives are equipped with the developed prototypes and the applicability of the technologies is tested according to the list of requirements. A Train Test Lab is a local site that has special characteristics and thus provides resources for special tests. The entire set of requirements cannot be tested exclusively in a Train Test Lab but will be distributed stepwise, in parallel to all other demonstrators planned in the project.

The goals pursued in the Train Test Lab can be divided into four areas of action. On one hand, a continuous trial and error process should enable the project participants to test ideas quickly and thus accelerate the development process. This creates an advantage for action through a faster exchange with the manufacturers on product versions that can be tested in the Train Test Lab at relatively short notice. Secondly, it must be possible to make decisions on component types at defined milestones within the project. The third line of action involves the approval-relevant tests. Within the Train Test Lab, tests are to be made possible in order to develop approval tests, but also to check the approvability of freight wagons and locomotives equipped with the new technical enablers. The fourth action area involves execution of demonstrations. Experts and workers from the entire sector should be able to understand the new technologies and contribute their know-how and knowledge to the development process.

The Havelländische Eisenbahn AG (HVLE) site in Berlin-Spandau successfully prevailed in the selection process. The Johannesstift station has been converted into a dedicated test site (see Figure 6). In addition to office workstations, project team members have access to a conference room and an electronics workstation. There is also sufficient storage space for couplers and electronic components. Siding tracks and test infrastructure complete the overall package.

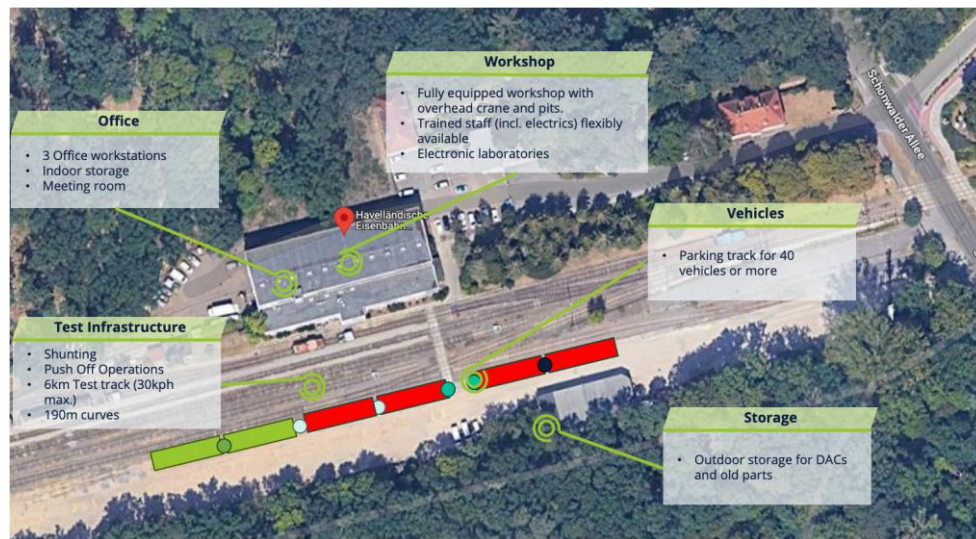


Figure 6 Train Test Lab in Berlin-Spandau

This site is particularly relevant for early tests and impact tests. Special infrastructure is required for other tests, such as running ability tests. For this purpose, selected vehicles were prepared at TTL and equipped with measurement technology and DACs. The group of test vehicles was then transported to the TÜV Süd facility in Görlitz. Additional test sites for validating the DAC in ERJU projects are shown in Figure 7.



Figure 7 FP5 test locations for DAC tests

Climate chamber tests were conducted in collaboration with DB Systemtechnik at the Minden site as part of the DACTivate project. In Mannheim, the installation tests described in DEL14.4 and DEL14.5 were carried out. In Q4 2026, tests are also planned in collaboration with SNCF in France to validate the benefits of the overall FDFT system.

5.2 System under test – DAC types

The focus of the tests relevant to this document is the Digital Automatic Coupler (DAC). Figure 8 shows the main components of a DAC. The draft gear is optimized for freight wagons with an installation space compliant with UIC 530 and can be installed in under 60 minutes [DEL 14.5]. It ensures force transmission to the wagon structure via tension and a compression stops. The coupler head is connected to the draft gear via a standardized bolt [EN 15566]. The connection between the coupler head and the draft gear is referred to as Interface A and is specified based on UIC 524 to technically enable the supplier-independent use of any coupler head on any draft gear. The coupler front part is the interoperable interface for mechanical force transmission to the next vehicle. In addition, pneumatic lines for the brakes can be coupled as well as power and data lines are automatically connected via the e-coupler. Since the coupler front part is attached to the draft gear assembly on a pivot, a vertical support is required for the correct alignment of the DAC. All DACs can be uncoupled via a manual control element under the coupler head. However, this is intended only for maintenance or emergency measures. In future operations, uncoupling is to be performed solely at the push of a button on the side of the wagon. To this end, modern DACs have been equipped with electric actuators.

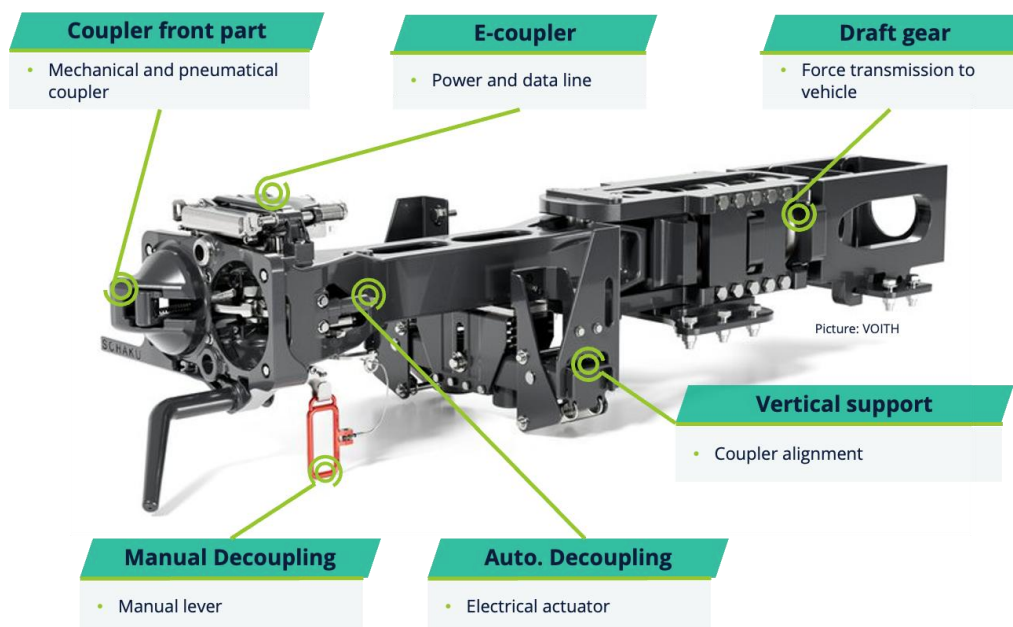


Figure 8 DAC overview and subcomponents

The DAC is standardized as an interoperable interface in many instances. It is based on the latch type principle, which is described in more detail in EN 16019. However, this standard primarily applies to passenger transport. In freight transport couplers must

withstand significantly higher loads. The findings determined in TRANS4M-R contribute significantly to the development of a separate standard for the DAC [EN 18171]. Mechanically and pneumatically, however, freight wagon couplers should be compatible with those used in passenger transport. Additional requirements for the DAC were generated in TRANS4M-R and summarized in DEL 5.2. A test specification for the DAC is included in DEL 5.3. Further details on the DAC in various configuration stages are included, for example, in DEL 6.3 and DEL 7.3.

Between first testing in September 2023 and March 2026, approximately 50 DACs were delivered by the four suppliers Dellner, Knorr-Bremse, Voith, and Wabtec. Over time, significant improvements in the systems were observed. In addition to an enhanced range of functions, modern DACs also feature improvements in derailment safety, installation time, and, in some cases, weight. Table 2 provides a summary overview of selected changes.

Table 2 DAC evolution over project time.

	Early Test Phase Start in 2023	Validation Test Phase Start in 2025
Suppliers	Dellner, Knorr-Bremse, Voith	Dellner, Knorr-Bremse, Voith, Wabtec
Uncoupling	Manual lever Initial tests with actuator and push button	Manual lever Push buttons over simulation box and actuator
e-coupler	Only first versions for design assessment	e-coupler provided by Voith
Draft gear	Multi-part configuration. Limited derailment protection; often difficult to assemble	Enclosure design with improved derailment protection. Improved installation suitability.
Interface A	Not Interface A ready	Interface A ready
Vertical support	Relocation of air cock is always necessary	Solutions available to avoid air cock relocation
Coupler front part	No proven interoperability No prevent coupling function With air valve	Proven interoperability with all suppliers Prevent coupling function with actuator Without air valve

Especially impressive are DAC developments shown in before-and-after images. Figure 9 compares two DACs from Dellner. The comparison for Knorr-Bremse can be seen in Figure 10. Figure 11 shows Voith, and Figure 12 shows the version of Wabtec tested in 2025. Since different DAC versions were used during the tests, the coupler system specific to each test is described in detail in each test report. Please refer to the corresponding appendices for this information.

Dellner DAC – Version in 2023



Dellner DAC – Version in 2025

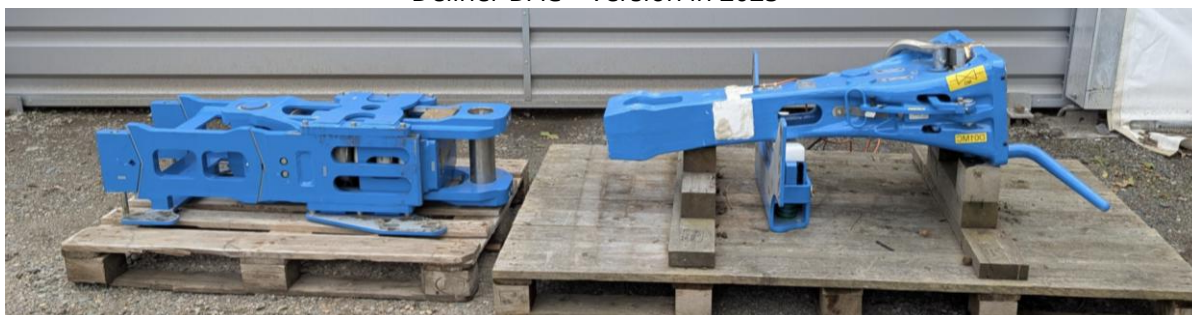


Figure 9 Evolution Dellner DAC

Knorr-Bremse DAC – Version in 2023



Knorr-Bremse DAC – Version in 2025



Figure 10 Evolution Knorr-Bremse DAC.

Voith DAC – Version in 2023



Voith DAC – Version in 2025

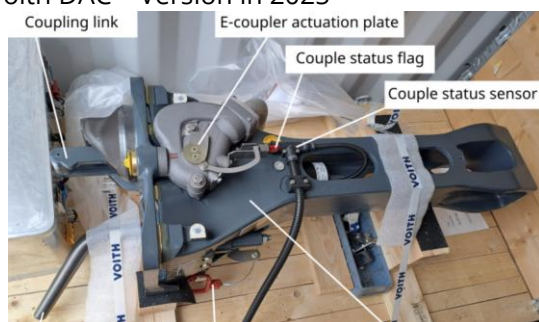


Figure 11 Evolution Voith DAC.

Wabtec DAC – Version in 2025



Figure 12 Wabtec DAC in 2025.

6 DAC - Early Testing

The testing activities executed in the WP14 can be divided into two phases. The early testing phase (chapter 6) during which general knowledge about the DAC and its functionality was derived, and the validation test phase (chapter 7) which derived relevant results for enabling the demonstrator trains.

During the early test phase, the focus was:

1. Gaining general knowledge about the DAC
2. First system integration of a DAC 2 to DAC 4
3. Assessment of different e-coupler types

A more detailed overview of the major test campaigns is given in the following sections. Numerous appendices have been added to this deliverable. These include selected test reports containing further details on the tests. The corresponding references can also be found in Table 3. The test reports included as annexes do not include confidential information (e.g. in terms of results) of the suppliers. The full reports can be requested at the relevant suppliers.

Table 3 Extract of executed tests in WP14.

Test	Period	Report
System integration – first functional tests	July 2023 – Apr 2025	DEL 14.4 and DEL 14.5
E-coupler assessment	Nov 2023 – Jan 2023	Annex 1 - 2024-001-WP14-TR01
Voith train separation	Feb 2024	Annex 2 - 2024-002-WP14-TR01
Armoured vehicle loading	Mar 2024	Annex 3 - 2024-003_ArmoredVehicleLoading
DAC2 Interoperability tests	Apr 2024 – May 2024	Annex 4 - 2024-006-WP14-TR01 Annex 5 - 2024-006-WP14-TR02 Annex 6 - 2024-006-WP14-TR03 See also DEL 6.3
Knorr-Bremse actuator tests	Aug 2024	Annex 7 - 2024-007-WP14-TR01
Voith air valve venting capacity tests	Dec 2024	Annex 8 - 2024-011-WP14-TR01
Dellner actuator tests	Jan 2025	Annex 9 - 2025-012-WP14-TR01
Early tests hybrid coupler with locomotive (TRAXX)	Mar 2026 – May 2026	To be submitted later

6.1 System Integration

The initial testing of components at TTL essentially involves installing them in relevant vehicles. Particularly in the case of initial deliveries of new prototypes, this was carried out in collaboration with the supplier. Figure 13 shows an example of a system integration test in the TTL workshop.

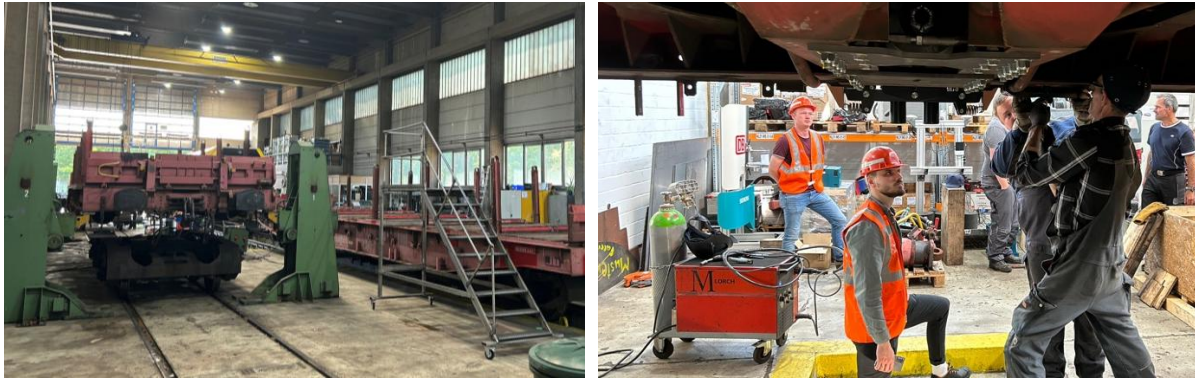


Figure 13 System integration tests in TTL workshop

6.1.1 Goal of the system integration tests in WP14

The goal of the system integration tests in WP14 is to optimize installation in terms of time and cost, as well as to evaluate the installation processes regarding the requirements for migrating the DAC. In addition to adjustments to the DAC by the suppliers, internal workshop processes should also be optimized. This includes, for example, an assessment of suitable lifting devices and tools, as well as the number and skill level of the technicians involved in the process. Significant potential for optimization was assumed, particularly during the preparation of wagons (e.g., removal of the SC, rerouting of the air pipe) and during the installation of the draft gear (see Figure 14). In addition to optimizing standard installation processes, other objectives included installation tests on vehicles without a UIC installation space and the installation of hybrid couplers in a TRAXX locomotive.

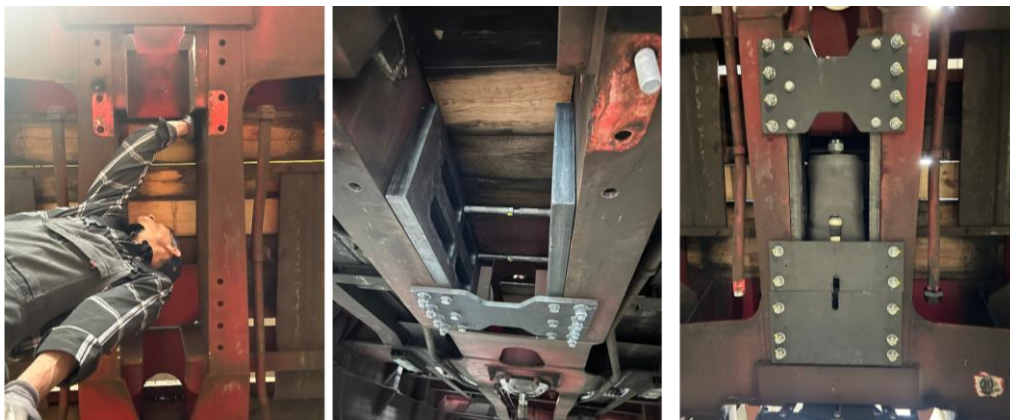


Figure 14 Draft gear installation steps.

6.1.2 Execution of system integration tests in WP14

The first installation tests took place already in July 2023. The latest DAC versions were installed for the first time in April 2025. However, since frequent conversions were necessary even during the tests, more than 100 system integration tests were carried out over the course of the project. In addition to the installation of a DAC, these tests also analysed its uninstallation process and serviceability.

During the planned migration phase of the DAC, the European sector will need more workshops than currently available. One idea to solve this problem is to set up numerous flexible “pop-up” workshops for a short period of time. These workshop tents combine current workshop repair methods with mobile trackside work. In WP14, such a workshop was therefore set up for testing purposes (see Figure 15). A large portion of the work was successfully carried out here and validated in collaboration with occupational safety and regulatory authorities.

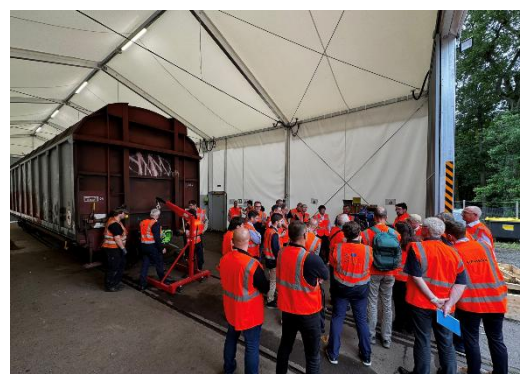


Figure 15 Mobile test workshop in TTL - demonstration of system integration.

Tests conducted on wagons without standard UIC installation space focused in particular on the T3000 wagon type (see Figure 16). In 2025, a detailed installation analysis and a test installation were carried out in conjunction with a specially designed draft gear from Voith.

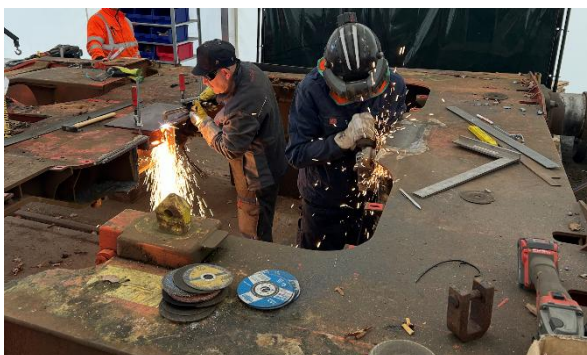


Figure 16 Modification of T3000 installation space and system integration of special DAC from Voith

Due to delivery delays, the system integration tests for hybrid couplings from Wabtec/Voith and Dellner could not be conducted until March 2026. Figure 17 shows the final modification work on both sides of the DB Cargo TRAXX BR 185 V2 locomotive.



Figure 17 Hybrid DACs installed in TRAXX locomotive (Dellner: left side, Voith/Wabtec: right side)

6.1.3 Results of system integration tests in WP14

Detailed results from the system integration tests are not included in this deliverable. However, [Annex 13] contains an analysis of the potential for optimizing the installation processes. The results regarding the installability of DACs from various suppliers are the focus of Task 14.5, which are included in DEL 14.4. System integration for special wagons such as the T3000 and locomotives is covered in detail in WP8, and the results are presented in DEL 8.2 and DEL 8.3.

6.2 Test for E-coupler Assessment

In the early testing phase, an assessment of e-coupler types was executed. The suppliers Knorr-Bremse and Voith each supplied one type of e-coupler, which were put under different tests by the WP14 from November 2023 to January 2024.



Figure 18 E-coupler concepts of Knorr-Bremse (left) and Voith (right).

6.2.1 Goal of e-coupler assessment tests in WP14

E-couplers in freight rail wagons face numerous challenges during operation which differ from those for passenger trains: High exposure of the components to mechanical loads (loading, unloading, hump yard shunting) and environmental influences (moisture, dirt, dust, etc.) require a high robustness of these components.

To assess the robustness and reliability of the two e-coupler types a group of experts within the TRANS4M-R project developed a list of criteria, which was transferred into test cases to be tested in the field. The following test cases were assigned to WP14 and tested within this test campaign:

Table 4 Relevant test cases and criteria for e-coupler assessment, assigned to WP14.

Test case name (Polarion)	Polarion ID	Criteria names	Criteria List Cell
e-coupler – Impact tests	[IP-TRANS 2399]	Impact test	A2 – 2.4
e-coupler - Installation and maintenance	[IP-TRANS 2388]	Bolting Special tooling Maintainability (incl. ease of exchangeability)	A14 – 14.2 A15 – 15.1 B2 – 2.1
e-coupler - manual access to pins	[IP-TRANS 2380]	Hand access to pins	A11 – 11.1
e-coupler - Movement area and interaction with wagon components	[IP-TRANS 2377]	Installation checks	A1 – 1.2

e-coupler – Influence of dirt	[IP-TRANS 6555]	Bucket full of dirt	A10 – 10.1
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6.2.2 Execution of e-coupler assessment tests in WP14

The test campaign was derived into tests for each of the test cases shown in Table 5.

Table 5 Test cases for e-coupler assessment tests

Test	Description
Impact tests	309 push-off operations and couplings with different wagon-loads and different impact speeds on different track geometries
Installation tests	5 e-coupler installations per supplier
Manual access to pins	Application of defined forces with the goal to gain access to the e-coupler pins
Movement area and wagon interaction	Deflection of couplers to analyse the interaction with wagon parts (e.g. flaps)
Influence of dirt	Forced pollution of e-couplers with different pollutants

The following infrastructure and assets were used to execute the tests:

Table 6 Infrastructure and assets for e-coupler assessment tests

Assets / Infrastructure	Description
Location	HVLE Berlin-Spandau – used tracks: straight track, switches and workshop
Wagons / traction	2 coil transport wagons 2 flat wagons 1 Shunting loco 200 t of loading
Couplers	2 DACs of supplier Knorr-Bremse (incl. 2 e-couplers) 2 DACs of supplier Voith (incl. 2 e-couplers)
Measurement system	2 field test measurement systems – installed by DBST Different manual measurement systems
Personnel	Test engineers Shunters Operational staff

6.2.3 Results of e-coupler assessment tests in WP14

Both e-couplers passed a majority of the executed tests. With the help of the results a decision for an e-coupler design was made within the project. Furthermore, general knowledge about the challenges of e-couplers in freight rail was gained.

The detailed test report 2024-001-WP14-TR01 has been restricted by industry partners and must be requested from the relevant supplier. The publicly available test report can be found in [Annex 1].

6.3 DAC 2 Interoperability tests

For DEL 6.3 different tests regarding the interoperability of DAC2 were executed within WP14. The suppliers Dellner, Knorr-Bremse and Voith were involved in the tests, which were executed from April to May 2024.



Figure 19 DAC 2 interoperability tests

6.3.1 Goal of DAC2 interoperability tests

In this test campaign tests defined in the DEL 6.3 were executed. As the design of the DAC2 was fixed to the latch type design, all suppliers delivered couplers of that type. Still the designs varied in different details, which required a test of the interoperability between the couplers of different suppliers.

The main goal was to prove the interoperability of the mechanical and pneumatical parts of the DACs.

6.3.2 Execution of DAC2 interoperability tests

281 impact tests were executed on different track geometries at the TTL location in Berlin-Spandau.

The following infrastructure and assets were used to execute the tests:

Table 7 Infrastructure and assets for DAC2 interoperability tests

Assets / Infrastructure	Description
Location	HVLE Berlin-Spandau – used tracks: straight track, switches and workshop
Wagons / traction	2 coil transport wagons 2 flat wagons 1 Shunting loco 200 t of loading
Couplers	4 DACs of supplier Dellner 2 DACs of supplier Knorr-Bremse 2 DACs of supplier Voith
Measurement system	2 field test measurement systems – installed by DBST

	Different manual measurement systems
Personnel	Test engineers Shunters Operational staff

6.3.3 Results of DAC2 interoperability tests

All couplers passed a majority of the executed tests. The results showed that minor weaknesses on all couplers existed. These did not lead to a critical failure and were communicated to the suppliers for an optimization of their couplers. Furthermore, general knowledge about the use of DACs in rail freight was gained.

Within the project, the tests raised questions regarding the needed reliability in terms of coupling and complete uncoupling of the DACs.

The detailed test report 2024-006-WP14-TR01 has been restricted by industry partners and must be requested from the relevant supplier. The public available test report can be found in [Annex 4], [Annex 5] and [Annex 6].

6.4 Additional early test examples

6.4.1 Armoured vehicle loading

Due to the additional space requirements of a DAC in the centre of the head stock, it must be ensured that the DAC does not inflict with any wagon part during operations. As the loading of armoured vehicles with flat wagons with flaps was expected to be the worst-case scenario, the movement of the wagon parts during loading of armoured vehicles was examined (see Figure 20).



Figure 20 Examination of armoured vehicle loading with measurement system.

The resulting measurement data and documented procedure of loading showed that the space requirement of the DAC does not inflict with the wagon during this scenario. The public available test report can be found in [Annex 3].

6.4.2 Voith train separation and air valve venting capacity

To prove the emergency brake function of current air valves Voith carried out tests within the WP14 in February 2024 during which a train separation was simulated. The DACs were manipulated to lower the breaking point of specific components. A force was applied onto DACs with the help of a loco, leading to a failure of the manipulated component and a separation of the wagons. Not every wagon separation led to an emergency brake.

The results influenced the projects decision to eliminate the air valve of the DACs until a suitable solution is found.

In December 2024 tests were executed within the WP14 during which different air valve diameters and their venting capacity were compared by Voith. The detailed test report 2024-002-WP14-TR01 (train separation) and 2024-011-WP14-TR01 (air valve venting capacity) have been restricted by industry partners and must be requested from the relevant supplier. The public available test report can be found in [Annex 2] and [Annex 9].

6.4.3 Knorr-Bremse and Dellner actuator tests

To validate the functionality of the developed actuators in the field, the suppliers Dellner and Knorr-Bremse executed field-tests of their actuators and electric systems in the WP14.

The detailed test report 2024-007-WP14-TR01 (Knorr-Bremse, August 2024) and 2025-012-WP14-TR01 (Dellner, January 2025) have been restricted by industry partners and must be requested from the relevant supplier. The public available test report can be found in [Annex 7] and [Annex 10].



Figure 21 Dellner actuator tests.

7 DAC Validation Tests

The goal of the validation tests phase was to validate the latest DAC versions from every supplier and to deliver relevant test results for enabling the upcoming demo trains.

To gain these results the phase was split into two parts:

1. Development of test scenarios defining the detailed test procedures based on the current state of the standards
2. Execution of tests based on the defined test scenarios

7.1 Definition of Test Scenarios

As described in section 3.4, test scenarios provide a detailed plan for the tests to be conducted. They initially include the results of a study of test requirements derived from available standards, particularly the TSI Wagons. Mostly, currently available standards are not fully applicable to test procedures for a DAC. Due to the change in the transmission of compressive forces through the centre, for example, the known tests for the validation of side buffers from EN 15551 are not fully applicable to the DAC and must be adapted. Another example is derailment safety tests according to EN 15839. Compared to the screw coupler, the DAC has significantly different derailment behaviour and is also designed to withstand significantly higher longitudinal compressive forces, before derailment occurs. To address the necessary adjustments, the presentation and discussion of the changes are part of every test scenario. This is followed by a description of the required vehicles, infrastructure, and measurement technology. Finally, the actual test process is described step-by-step, and the criteria for a successful test are presented.

The selection of required test campaigns was carried out in WP13 in collaboration with WP4 for approval-related tests. In addition, the test specification [DEL 5.3] developed in WP5 was used as the most important input, together with the relevant standards. The defined test campaigns are shown in Table 8. Not all the test campaigns were carried out within the TRANS4M-R project. Derailment safety and climate chamber tests were conducted within the DACtiVate project. Due to the delayed start of the DACtiVate project, the preparatory work for this test campaign was carried out under WP14 of the TRANS4M-R project.

Table 8 Overview of test scenarios written within the WP14.

Test scenario	Document	Execution in
Running safety under longitudinal compressive forces (Derailment)	[Annex15]	DACtiVate WP1
Impact tests	[Annex16]	TRANS4M-R WP14
Running ability tests	[Annex17]	TRANS4M-R WP14
Climate chamber	[Annex18]	DACtiVate WP1

All test scenarios were reviewed and approved by WP13 and the participating industry partners. Final approval of the test scenarios was then granted by WP4 in March 2026, shortly before the start of the first test campaign in DACTivate in June. Tests executed in WP14 are summarized in the following chapters.

7.2 Running Ability Test

In WP14 the tests regarding the test scenario “running ability tests” [Annex17] were executed. Couplers of the suppliers Dellner, Faiveley (Wabtec), Knorr-Bremse and Voith were tested from June 2025 to August 2025 at the location of the TÜV Süd in Görlitz.

7.2.1 Goal of the running ability tests

In this test campaign the tests defined in the relevant test scenario were executed. The main goal is to prove the functional safety of the DAC during train runs and the unrestricted operability regarding track geometries. Furthermore, the interoperability should be proven.



Figure 22 Test on ferry boat ramp



Figure 23 Coupling and decoupling in different infrastructure

7.2.2 Execution of the running ability tests

192 running ability tests on different track geometries at the location of the TÜV Süd in Görlitz were performed.

The following infrastructure and assets were used to execute the tests:

Table 9 Assets and Infrastructure for running ability tests

Assets / Infrastructure	Description
Location	TÜV Süd Görlitz – used tracks: straight track, ferry boat ramp, 150m s-curve, 75m curve and workshop
Wagons / traction	2 four-axle sliding wall wagons 4 two-axle sliding wall wagons 1 Shunting loco 200 t of loading
Couplers	3 DACs of the supplier Dellner 3 DACs of the supplier Faiveley 3 DACs of supplier Knorr-Bremse 3 DACs of supplier Voith
Measurement system	4 field test measurement systems – installed by DBST Different manual measurement systems
Personnel	Test engineers Shunters Operational staff

7.2.3 Results of the running ability tests

During the tests it was found that the e-coupler supplied by Voith did not fit onto specific DACs. Furthermore, standardized hole patterns for vertical support on the front of some wagons were found to not be within the tolerances.

Regarding the running ability itself, all couplers passed the tests.

The detailed test report 2024-014-WP14-TR01 has been restricted by industry partners and must be requested from the relevant supplier. The public available test report can be found in [Annex 7] and [Annex 10].

7.3 Impact Tests

In WP14 the tests regarding the test scenario “impact tests” [Annex15] were executed. Couplers of the suppliers Dellner, Faiveley, Knorr-Bremse and Voith were tested from June 2025 to February 2026 at the location of the TÜV Süd in Görlitz and the HVLE in Berlin-Spandau.



Figure 24 Impact tests in TTL during winter 2025/2026

7.3.1 Goal of the impact tests

In this test campaign the tests defined in the relevant test scenario were executed [Annex15]. The main goal functionality and structural strength of the DAC during shunting operations. Furthermore, its operational functionality regarding coupling on different track geometries shall be proven. Tests were executed interoperable.

7.3.2 Execution of the impact tests

450 impact tests were executed on different infrastructures at the locations of the TÜV Süd in Görlitz and the HVLE in Berlin-Spandau.

The following infrastructure and assets were used to execute the tests:

Assets / Infrastructure	Description
Location	TÜV Süd Görlitz – used tracks: straight track, ferry boat ramp, 150m s-curve, 75m curve and workshop HVLE Berlin-Spandau – used tracks: straight track and workshops
Wagons / traction	2 four-axle sliding wall wagons 4 two-axle sliding wall wagons 1 Shunting loco 300 t of loading
Couplers	4 DACs of the supplier Dellner 4 DACs of the supplier Faiveley 4 DACs of supplier Knorr-Bremse 4 DACs of supplier Voith
Measurement system	4 field test measurement systems – installed by DBST Different manual measurement systems
Personnel	Test engineers Shunters Operational staff

7.3.3 Results of the impact tests

Critical damages were found on the draft gear of a specific supplier and the e-couplers. The results were evaluated by the UEG as part of Quality Gate 2.

Overall, the DAC's suitability was demonstrated even under very high forces and in various infrastructure settings. In addition, the interoperability of the prototypes tested among participating suppliers was confirmed. Functionality and interoperability of the prevent coupling position were also successfully verified.

The detailed test reports 2024-014-WP14-TR01 and 2024-015-TR01 have been restricted by industry partners and must be requested from the relevant supplier. The public available test report can be found in [Annex12].

8 Conclusions

This deliverable provides an overview of field tests involving DAC-equipped vehicles within a closed test environment (TrainTestLab). The tests were divided into two phases. During the early test phase, the objectives were to select designs for various subsystems, confirm the feasibility of requirements and test procedures, and conduct early analyses of initial prototypes to support the development process. In the validation test phase, final prototypes were tested in accordance with defined test scenarios and requirements. The focus of the tests was always on demonstrating the interoperability of a DAC. All tests within the validation test phase were therefore conducted with all relevant supplier combinations. The corresponding test reports are attached to this deliverable in general form. Due to confidentiality, the detailed supplier-specific test reports are available only to the suppliers and the user expert group within TRANS4M-R. Together with additional validation tests from the DACtiVate project, it was demonstrated that the DAC is capable of meeting requirements and important evidence for preparing the DAC's authorization was obtained.

Since safe operation of certain supplier-specific DAC solutions, as well as their interoperability, has been demonstrated, the focus has now shifted to investigating their operational use within demonstrator trains in WP15, WP16, and WP17. Within WP14, the focus of the investigations is now shifting toward the use of power and data systems, as well as train functions. The results of these tests will be summarized in DEL 14.3 at the end of 2026. Within WP13, a summary of all tests at vehicle level and train level, with a focus on the overall FDFT system, will also be prepared by the end of the project.

9 References

Abbreviation	Document-Nr.	Title	Author	Date	Version
[DEL13.1]	-	TRANS4M-R - D13.1 System Integration Plan & Test Concept for DAC components	Anna Björkman	22.12.2022	1
[DEL13.2]	-	TRANS4M-R - D13.2 Consolidated full system integration plan, test concept & validation concept and plan	Anna Åkerman	11.04.2024	4
[DEL 14.4]	-	TRANS4M-R – D14.4 (public) Report on installability and serviceability	Uwe Schwedhelm	30.03.2026	1
[DEL 14.5]	-	TRANS4M-R – D14.4 (sensitive) Report on installability and serviceability	Uwe Schwedhelm	30.03.2026	1
[DEL 6.2]	-	TRANS4M-R – D6.2 DAC Level 4 (incl. Level 2+) Interoperability Report	Johan Ahman	30.04.2025	3
[DEL 6.3]	-	TRANS4M-R – D6.3 DAC Level 4 couplers for testing on trains lab.	Ulrich Deghela	30.06.2025	4
[DEL 7.1]	-	TRANS4M-R – D7.1 DAC Level 5 – functional test report	Stefan Faas	30.01.2026	3
[DEL 7.2]	-	TRANS4M-R – D7.2 DAC Level 5 – interoperability report	Leonid Perdujan	27.02.2026	2
[DEL 7.3]	-	TRANS4M-R – D7.3 DAC Level 5 couplers for testing on train lab	Johanna Wiklund	27.02.2026	1
[DEL 8.2]	-	TRANS4M-R – D8.2 Wagon-DAC against DAC for Non-UIC-pocket-wagons	Andreas Schuhmacher	02.2026	3
[DEL5.2]	-	TRANS4M-R – D5.2 Technical Specifications of Wagon and Locomotive DAC up to Level 5	Johan Ahman	20.12.2023	1
[DEL5.3]	-	TRANS4M-R – D5.3 Validation/Test Procedures of Wagon and Locomotive DAC up to Level 5	Andreas Schuhmacher	31.10.2023	4
[DEL4.3]	-	TRANS4M-R – D4.3 DAC Running Safety Assessment Tool	Daniel Jobstfinke	07.02.2025	1
[TSIWAG]	321/2013	TSI Wagon COMMISSION REGULATION (EU) No 321/2013 of 13 March 2013 concerning the technical specification for interoperability relating to the subsystem 'rolling stock - freight wagons' of the rail system in the European Union and repealing Decision 2006/861/EC (Text with EEA relevance)	European commission	13.03.2013	-
[EN14363]	EN 14363:2016 +A12028	Railway applications Testing and simulation for acceptance of running characteristics of railway vehicles – Running behaviour and stationary tests; German version EN 14363:2016+A1:2018	DIN-Normenausschuss - FSF	01.11.2019	-
[UIC530]	UIC 530-2	Railway applications – Freight wagons –	International	01.12.2005	5

Abbreviation	Document-Nr.	Title	Author	Date	Version
		Running safety – 5 th Edition	Union of Railways (UIC)		
[UIC524]	UIC 524	International Union of Railways (UIC), UIC Leaflet 524: Wagons - Technical specifications governing spring devices for wagons fitted with automatic couplers belonging to the UIC and OSJD member railways	International Union of Railways (UIC)	1978	-
[EN15839]	EN 15839:2012 +A1:2015	Railway applications Testing for the acceptance of running safety under longitudinal compressive forces; German version EN 15839:2012:A1:2015	DIN-Normenausschuss - FSF	01.01.2016	-
[DAC4EU01]	60226-TT.TVP22-PR01-V2	Testing: Digital automatic coupling Phase I Testing of running safety under longitudinal compressive forces – Final report	DB Systemtechnik	03.12.2021	2
[El-Sibaie]	-	M. El-Sibaie, „Recent advancements in buff and draft testing techniques,“, Proceedings of the 1993 IEEE/ASME Joint Railroad Conference, pp. 115-119	IEEE/ASME	1993	-
[GA]	Project 101102009	GRANT AGREEMENT Project 101102009 – FP5 – TRANS4M-R – HORIZON_ER_JU-2022-01	FP5-TRANS4M-R	2022	1
[EN 16019]	EN 16019:2014, 5.1	Railway applications - Automatic coupler - Performance requirements, specific interface geometry and test method	DIN-Normenausschuss - FSF	2014	1
[EN 18171]	prEN 18171: 2025	Railway applications - Railway rolling stock - Digital freight automatic coupler - Performance requirements specific interface geometry and test method	DIN-Normenausschuss - FSF	2025	2

10 Appendices

Annex	Title	Content
[Annex01]	2024-001-E-coupler assessment TTL_Extract	Extract of test report for e-coupler assessment (164 pages)
[Annex02]	2024-002-Unintentional decoupling_Extract	Extract of test report for early test VT (16 pages)
[Annex03]	2024-003_ArmoredVehicleLoading_Presentation_DE	Test result presentation GER (11 slides)
[Annex04]	2024-006-Interoperability - Early testing - Dellner_Extract	Extract of test report for Dellner DAC 2 interoperability (66 pages)
[Annex05]	2024-006-Interoperability - Early testing - Knorr-Bremse_Extract	Extract of test report for Knorr-Bremse DAC 2 interoperability (66 pages)
[Annex06]	2024-006-Interoperability - Early testing - Voith_Extract	Extract of test report for Voith DAC 2 interoperability (66 pages)
[Annex07]	2024-007-KB Actuator tests_Extract	Extract of test report for KB Actuator tests (8 pages)
[Annex08]	2024-008-Installation Axtone Voith draft gear_Extract	Extract of test report for VT draft gear installation (6 pages)
[Annex09]	2024-011-Nominal breaking point_Extract	Extract of test report for VT nominal breaking point test (15 pages)
[Annex10]	2025-012-Actuator Test Dellner_Extract	Extract of test report for Dellner actuator test (20 pages)
[Annex11]	2025-014-Running Ability and Impact Tests on special Infrastructure -V01_Extract	Extract of test report for Running Ability and Impact Tests on special Infrastructure (110 pages)
[Annex12]	2025-015-Impact tests and prevent coupling -V01_Extract	Extract of test report for Impact tests and prevent coupling test (114 pages)
[Annex13]	2024-Optimierung von migrationsfähigen Montageprozessen zu Digitalen Automatischen Kupplungen für den Schienengüterverkehr	Bachelorthesis – Optimization of migration-compatible installation processes for digital automatic couplers used in rail freight transport – only in German (75 pages)
[Annex14]	2025-013-DAC-TS01 TestScenario Derailment V05	Test Scenario for derailment tests
[Annex15]	2025-014-DAC-TS01 TestScenario Impact Test -V04	Test Scenario for impact tests
[Annex16]	2025-015-DAC-TS01 TestScenario Running Ability Tests V04	Test Scenario for running ability tests
[Annex17]	2025-016-DAC-TS01 TestScenario Climate Chamber V04	Test Scenario for climate chamber tests