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1. Introduction

1.1 Origin and objectives of MODTRAIN

In the late 20th century, the European Union identified as one of its key objectives the need to revitalise the rail sector in order to meet the challenges of ever-increasing demand for freight and passenger transport. In order to support the rail sector in boosting its competitiveness, the EU launched a first and then second legislative package. In these packages, the Commission developed the Interoperability Directives, which set basic standards to ensure safe and uninterrupted rail traffic on the Trans-European Network.

Motivated by the potential gains in competitiveness, the supply industry and railway operators decided to go beyond the regulatory framework with the launch of several research programmes, one of the most successful of which is considered to be MODTRAIN.

MODTRAIN stands for *Innovative Modular Vehicle Concepts for an Integrated European Railway System*. When it was launched, it was the first integrated project of its kind in the area of joint European railway research. MODTRAIN aims to define and demonstrate the necessary functional, electrical and mechanical interfaces and validation procedures to deliver a range of interchangeable modules which will form the basis for the next generation of intercity trains and universal locomotives. The concept of modularity aims to create economic advantages for both railway suppliers and operators such as reduced manufacturing costs and enhanced economies of scale, greater productivity of new rolling stock and improved reliability due to proportionally higher use of service-proven components in rolling stock design.

Co-financed by the European Commission under the 6th Framework Programme for Research and Technological Development, this €30.4 million project brings together 37 partners active in the railway sector: systems integrators, railway operators, sub-system suppliers as well as railway research centres and universities.

1.2 Structure of the project

The MODTRAIN project covers four principle areas of train architecture, which are mirrored in the sub-project structure (see figure 1):

- running gear (MODBOGIE), led by AnsaldoBreda
- train control and monitoring system (MODCONTROL), led by Alstom
- on-board power system (MODPOWER), led by Siemens
- man-machine and train-to-train interfaces (MODLINK), led by FAV Berlin and Bombardier

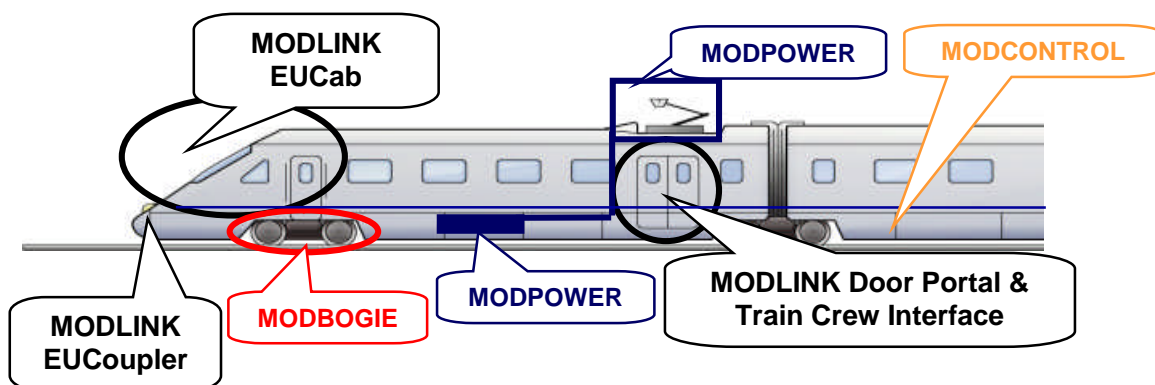


Figure 1: Representation of the areas covered by each sub-project

For the purposes of completeness, it should be noted that the European MODBRAKE project, dedicated to the standardisation of the brake system, was launched two years after MODTRAIN.

Though the sub-projects cover a variety of areas of investigation, they were nonetheless integrated in one overall structure. The project's Technical Management Team (TMT), made up of the sub-project leaders, played a key role ensuring the consistency and cross-fertilisation of the different sub-projects.

Whereas the TMT served to ensure internal coordination, MODUSER, the users' platform (and fifth sub-project), was created to ensure the dissemination of the results across the sector as a whole. This body enabled other players in the sector – operators and manufacturers – not directly involved the project to make an indirect contribution. In this sense, the role of the National Associations, representing their national SMEs, has been central.

1.2.1 Four sub-projects, one goal, one methodology

Though the MODTRAIN project is composed of four different sub-projects, they all share one aim – to boost rail competitiveness through standardisation and modularisation – and a common methodology.

The project started by compiling the requirements ensuing from either European legislation (Technical Specifications for Interoperability – TSI), European standards (ENs) or operator standards (Operational Requirements Specifications – UIC Leaflet 612).

A complete set of Functional & System Requirement Specifications were then developed based on a set of standardised Functional Requirement Specifications (FRS).

Finally, the main interfaces to be standardised were identified and the related standards drafted.

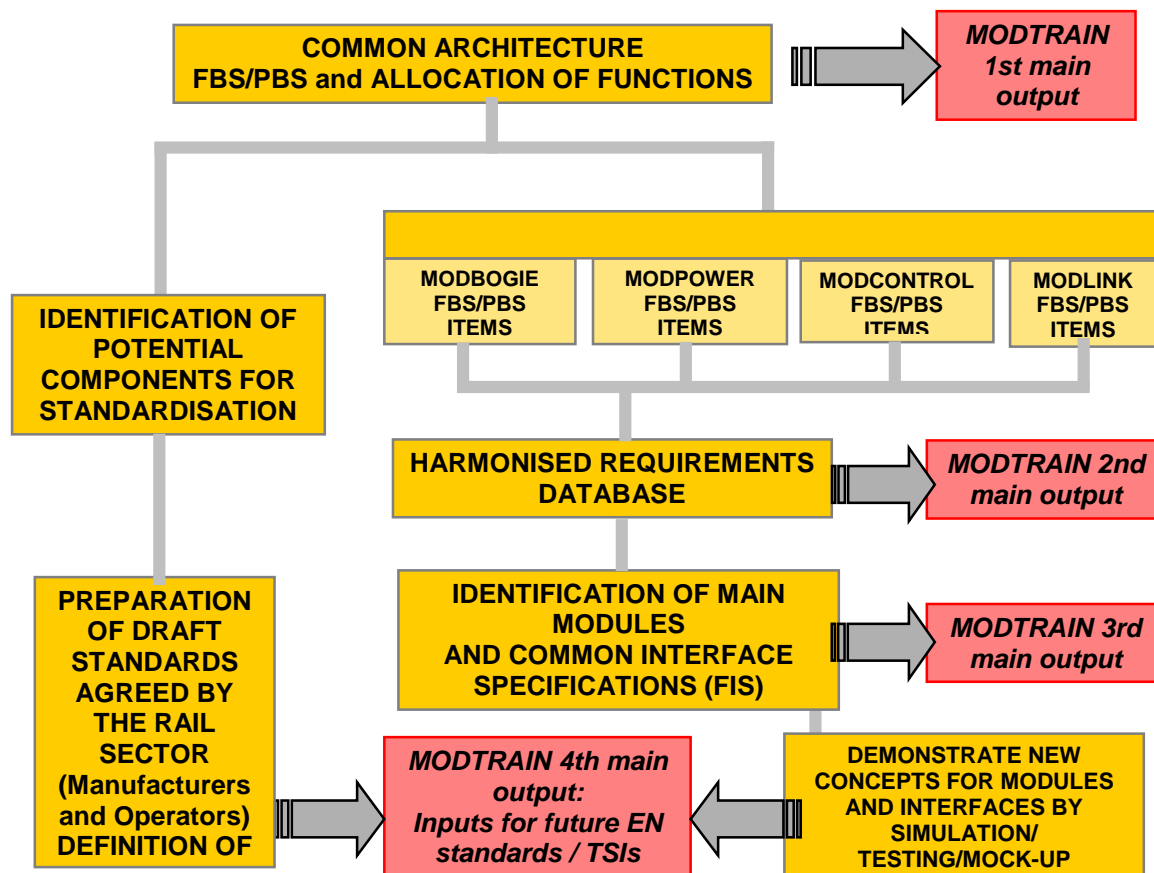


Figure 2: MODTRAIN methodology & road map

1.2.2 MODTRAIN achievements

The commitment of the various partners over the last four years ensured that MODTRAIN successfully achieved its main goal. Some of the project deliverables are now being processed by the European standardisation organisations (CEN / CENELEC) on their way to becoming future European standards (ENs). The present brochure presents in detail those MODTRAIN deliverables which have an impact on the sector, irrespective of the future status they may acquire in CEN/CENELEC.

MODTRAIN also paves the way for a new type of cooperation between the various players in the sector. Above and beyond the mandatory requirements defined in European regulations, MODTRAIN proves that voluntary harmonisation is both feasible and contributes to the objectives of greener, safer and faster trains for Europe.

2. Detailed subprojects outcomes

2.1. MODBOGIE

The MODBOGIE sub-project, led by AnsaldoBreda and supported by Politecnico di Milano, focused its work on standardisation issues in order to harmonise the reference functional and physical interfaces, operational requirements and acceptance procedures for the interchangeable modules to be supplied and fitted to the next generation of high speed trains.

Work centred on the definition of interchangeable bogie components (dampers, wheel sets) and the relevant testing and acceptance procedures, focusing on two key issues: the first relating to full standardisation of overall dimensions and mountings (geometrical interchangeability); the second intended to harmonise performance (full interchangeability).

In order to meet this challenge, a breakdown of bogie-relevant functions (FBS) and components (PBS) was first produced, with a detailed analysis performed of the operational requirements associated with each component in the PBS, taking account of both systems integrators' and operators' needs.

In the second phase of the work, the technical possibilities previously identified were evaluated and assessed with respect to both functional and non-functional requirements. This evaluation was performed in WP4 of the sub-project, using advanced calculation methodologies enabling accurate digital models for the study of vehicle dynamics and durability assessments to be developed.

The outcome of this work was used, together with the harmonised requirements, to establish a harmonised acceptance procedure (WP5) for the most critical bogie components (i.e. wheels, axles, dampers, etc.).

Finally, extensive testing activity was performed in order to demonstrate the critical points highlighted during the previous phases (WP6).

The evaluation of the critical aspects associated with the wheelsets, wheels and dampers led to the drafting of change requests to the current EN standards.

Dampers

Dampers, particularly yaw dampers, play an important role in the running dynamics of a high speed train. Today, despite their fundamental importance, dampers do not appear to be an interchangeable component as regards their dimensions, mountings, or standardised performance. Complete standardisation of their overall dimensions and fixing points is first needed in order to obtain geometrical interchangeability.

However, in order to achieve full interchangeability, it is very important to develop a testing method able to clearly ascertain performance levels. For this reason, a suitable test rig has been set up in Politecnico di Milano's experimental labs. The damper is mounted on the bench, together with a hydraulic actuator, which applies the necessary displacement to the mobile end. The aim of the test is to determine the frequency-dependant elastic and viscous characteristics of the component. The typical behaviour of a yaw damper has been fully investigated: usually the stiffness value increases with frequency, while the equivalent viscous damping decreases with frequency.

The results obtained on the test bench, together with the harmonisation of the overall dimensions and mountings, led to the drafting of a change request to the current EN standard.

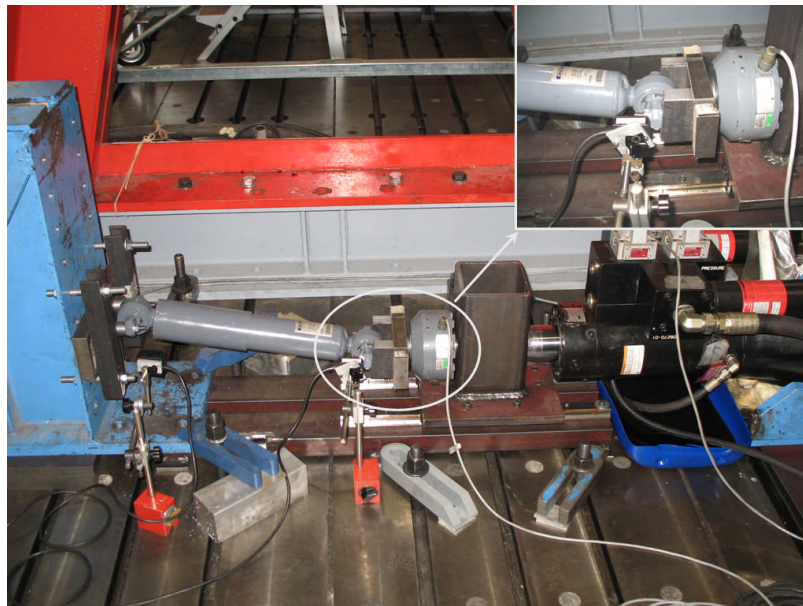


Figure 5: damper test bench

2.2. MODPOWER

MODPOWER represents innovative onboard energy supply and distribution systems.

Electrical energy is needed onboard for the three different sub-systems: the traction system, the auxiliary power supply and the uninterruptible low-voltage power system. An analysis of the systems used on modern passenger rolling stock showed a variety of different solutions. In particular, standardisation is still lacking for the auxiliary power supply systems and the train-line voltage used for auxiliary energy distribution along the train. Proprietary onboard voltage systems are used on some trains, with voltage characteristics different from those used by the national grid. This lack of standardisation renders a variety of auxiliary loads necessary to perform the same function, and power requirements thus depend exclusively on the type of supply voltage.

The European MODTRAIN research project and its sub-project MODPOWER, addressing onboard electric power supply, offered an opportunity to analyse the applicable system architectures in a working group consisting of key stakeholders in the rail sector. Innovative target solutions were developed and evaluated, rendering possible the following standardisation measures.

A comprehensively-applied systems approach, starting with basic operational and functional requirements, enabled generic system architectures for onboard energy supply systems to be developed based on these purely functional needs. This approach demonstrated its validity as a method, resulting in a minimum range of options needed to cope with the basic requirements defined.

Effective parameters for the design of onboard electric supply systems can only be achieved in the long term by including the main stakeholders in the consensus process, designing credible solutions, demonstrating the practical benefits of the relevant verification thereof, and turning project-internal commitments into standards. These conditions were established by the MODTRAIN project. This success was made possible by the willingness of partners to cooperate and set aside competition over specific sub-systems in order to reduce LCC and increase system performance and availability.

Standardisation at systems level was complemented by extending the approach to auxiliary loads and essential interfaces within the supply system. The explanations in the following chapters summarise the systems approach adopted, and give a comprehensive overview of the constituent elements of MODPOWER standardisation and its needs.

Designing projected systems for onboard power supply in future

The analysis of auxiliary power supply systems showed a variety of solutions encompassing single-pole AC and DC distribution facilities, dual-pole DC train power lines and various 3 AC supply grids with sine wave-filtered or pulsed voltages for energy distribution along the train. 3 AC systems differ further in their use of a neutral pole and monitoring of the train-line voltage frequency to reduce noise and optimise energy consumption. By contrast, the power supply and distribution systems supplying auxiliary loads in the coaches used on European locomotive-hauled passenger trains are largely standardised using single-pole train-line voltages in accordance with UIC 550. Harmonisation of supply systems for this kind of rolling stock is therefore limited to coach-internal equipment.

All systems architectures for onboard electrical energy can be traced back to a few core conversion, transformation and distribution functions. For instance, each system architecture includes a conversion stage converting energy from the traction unit into an appropriate voltage system feeding the distribution grid. Following the collection and evaluation of basic functional requirements, the second step of the applied systems approach is the definition of a set of core functions for all three electrical energy supply systems. The third step is finding appropriate technical solutions for the basic functions identified e.g. using existing or innovative design solutions.

This step-wise approach is called morphological analysis, and encourages system designers not to stick to familiar, tried-and-tested systems, instead helping them find optimised architectures by using new combinations of existing and innovative designs.

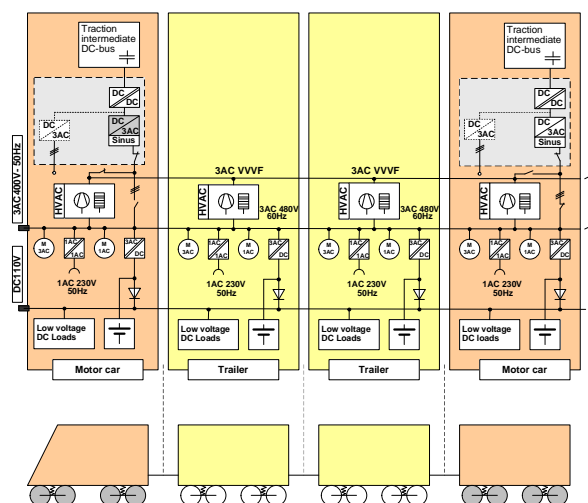


Fig.6: Projected system architecture for trains with distributed power, 3AC FF train-line, centralised 3AC VVVF for HVAC units

This mode of analysis can be used for more than exclusively technical issues, in this case leading to target architectures both for trains with distributed and concentrated power as well as for locomotive-hauled passenger trains, which demonstrate many of the same system features, such as train-line voltage, shore ground supply system, battery voltage, HVAC system supply and power supply to passenger sockets in coaches. An example of a representative system architecture is given in Figure 6, which describes one such target system for trains with distributed power using a sine wave-filtered 3 AC fixed-frequency supply facility for all auxiliary loads except HVAC units, which are connected to a centralised 3 AC VVVF train-line. Only in the unlikely event of a converter failure will the fixed/variable-frequency train-line be short circuited and fed by fixed-frequency voltage alone. This centralised variable-frequency supply will prove its worth by enabling power consumption reductions during operations without a concomitant significant increase in initial costs e.g. for additional converters. This supply system is therefore to undergo detailed verification by an appropriate system simulation as well as vehicle tests during one year's normal service.

Multi-physics system simulation, an innovative method for verifying complex architectures

Multi-physics simulation offers an appropriate means of measuring and verifying the designed generic system architectures in complex systems, including realistic operational principles. Dynamic system operation can be simulated with sufficient accuracy by a detailed control system model able to describe communication between the sub-systems and the high-level control of a train. In designing this innovative simulation, MODPOWER's objectives were twofold: on the one hand component features were to be emulated with sufficient accuracy, and on the other hand the system models developed were to be largely independent simulation tools which would facilitate cooperation between project partners. These objectives were achieved for representative system sub-sections by using a unified model description language (VHDL-AMS), which is currently mainly used in the automobile sector. The system simulation applied describes the system performance, the behaviour of the train control functions, and the operation of representative outputs of the three electrical energy supply systems. It can serve a wide range of purposes, from stationary analysis through to complex system dynamics caused by failures in the energy supply systems' central converters necessitating a complete reconfiguration of the onboard supply systems.

The simulation of electric and thermal effects on an innovative centralised variable-frequency supply for HVAC units posed a particular challenge. The multi-physics system simulation method used proved able to analyse this interdisciplinary electric and thermal behaviour together with its complex communication between sub-systems and TCMS. It was possible to develop optimised control strategies for the pre-control performed by the central auxiliary converter and for the individual coach control by the HVAC unit itself. Only an optimised control principle can ensure the desired level of climate comfort whilst simultaneously making the expected energy savings. In addition, this kind of simulation is able to realistically calculate the expected energy savings in operations in a complex climatic environment.



Figure 7: SNCF Z-TER test vehicle for testing the centralised variable-frequency supply for HVAC units developed during the project

Vehicle tests on a modern French Z-TER train are planned to close the applied system design loop, which started from concepts and was then analysed by system simulation before finally being validated by data recorded on a train in regular service. The concept of the variable-frequency supply will be introduced in the test vehicle by modifying the auxiliary converter and HVAC units in one half of the train. The other half will remain unchanged, enabling a direct comparison of differences in energy consumption.

The test train will be fitted with measurement equipment to observe the operation of the control system and measure the energy consumption of the air-conditioning run in normal operations over a period of one year.

Transforming the results achieved into CLC documents will ensure the future application of MODPOWER results

The aim of MODTRAIN and MODPOWER is to support interoperable rail traffic, to improve the competitiveness of the railways compared to the road sector and to increase modal share in favour of public transport. These essential objectives tie in directly with the removal of national barriers supporting borderless traffic within Europe, as well as with the reduction of procurement and operational costs.

MODPOWER’s results serve mainly to increase competitiveness by reducing LCC and simultaneously increasing the reliability and availability of rolling stock.

These objectives may be achieved by transforming the results of this research into CENELEC standards and Technical Specifications. In addition, standardisation and a broader testing scope will contribute significantly to developing more mature onboard energy supply systems, resulting in better system performance and increased availability of the electric energy supply.

In order to meet these demanding objectives, the standardisation project launched by MODPOWER followed a clear hierarchy, starting at architectural level by defining the basic system requirements and core system features e.g. train voltage, and by characterising the supply to the main auxiliary loads such as HVAC units. These core features were derived from both existing and innovative architectures and served to standardise important system components and interfaces as described below. The standardisation of the sine wave-filtered 3 AC train-line voltage generated by the main auxiliary converter obviously forms the backbone of this harmonised auxiliary supply system. A unified shore or external supply completes the standardisation at system level and defines the voltage system, protection features and mechanical design of the plugs and sockets used. These measures will be of benefit for the maintenance of interoperable rolling stock.

The MODPOWER standardisation process was concluded by developing specifications for variable auxiliary loads, which are widely used within the auxiliary system. In order to save costs, especially during railway operations, standardisation at this level had to target product standardisation and interface definitions enabling full interchangeability. Representative products using such loads are batteries, which need to be replaced several times during a train’s service life.

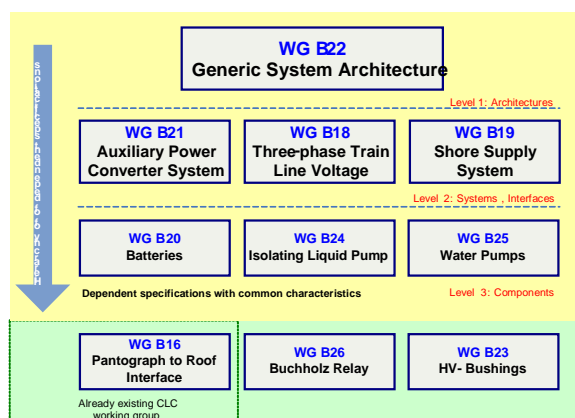


Figure 8: Overview of standardised components introduced into CENELEC TC9X/ SC9XB by MODPOWER

Figure 8 gives an overview of the scope of standardisation. The specifications prepared by MODPOWER were accepted by CENELEC TC9X as draft versions for Technical Specifications and EN standards.

For most of the components to be standardised, kick-off meetings were organised by the working groups in February 2008, starting with a mature technical appraisal.

In conclusion, the systems approach applied by MODPOWER was able to link technical solutions back to their operational and functional needs, and was the key to achieving consensus whilst strictly adhering to the MODTRAIN project objectives.

2.3. MODLINK

MODLINK was responsible for defining, testing, specifying and standardising interoperable man-machine interfaces (MMIs) for train drivers, onboard staff and passengers. MODLINK also tackled train-to-train data interfaces. Co-chaired by Bombardier Transportation, FAV Berlin and UIC, MODLINK was the biggest MODTRAIN sub-project, with a budget of circa € 11.5 million.

MODLINK was divided into workstreams in accordance with the area affected: EUCAB (train driver MMI), EUPAX (staff and passenger MMI), and EUCOUPLER (train-to-train data interface). The MODLINK methodology was the same as that used for the MODTRAIN process as a whole: based on the Functional Breakdown Structure (FBS) and Product Breakdown Structure (PBS) developed and applied throughout MODTRAIN, those items relevant to MODLINK were identified for further investigation, development, implementation, testing and standardisation. Due to the differences in background, conditions and R&D approaches, the MODLINK workstreams were structured separately according to the processes described below. In each case, sustained interaction between manufacturers, operators and researchers underpinned the process leading from scientific investigations to the test results and their conclusions, and proposals for European standardisation.

2.3.1 EUCAB

The EUCAB workstream aimed to create a harmonised working environment for European train drivers. Work therefore built on former European projects such as EUDD, SAFETRAIN, TRAINCOM, etc. Further input on the EUCAB project was provided by in-depth analysis of drivers' cabs in state-of-the-art rolling stock (locomotives and multiple units). The next step used an iterative process to define the Functional Requirements Specifications (FRS) and System Requirement Specifications (SyRS) for the main driver's cab sub-systems, drawing on the industrial and operational expertise of all project partners.

In particular, the Operational Requirements Specifications (ORS) 612-0 "Driver-machine interfaces for locomotives and motor coaches" provided by the MODTRAIN Operator Group played an important role in the EUCAB development process. This document, which has since been codified as UIC Leaflet 612, defines harmonised functional and operational requirements for train drivers' working environment and has been approved by SNCF, Trenitalia, Deutsche Bahn and other operators involved via UIC. Development of the ORS and FRS took place in a process of close interaction, including review loops. This procedure avoided time being lost in the incremental process, though it required additional efforts in terms of coordination.

The initial EUCAB results and the design mock-up were presented at the MODLINK midway conference held in Berlin in February 2006, and as part of the display of the combined EUCAB-EUPAX mock-up at the InnoTrans trade fair in September 2006, also held in Berlin (see figure 9). In particular, the prominent, physical presentation at InnoTrans considerably increased the attention paid to the MODTRAIN project as a whole.

The design and scope of the EUCAB functional testing on the sophisticated SNCF simulator in Lille was defined following ergonomic testing of the InnoTrans mock-up by drivers from several countries, and using the updated ORS 612 and relevant FRS/SyRS. Operators and manufacturers agreed to test three desk configurations (two versions for loco operation, one version for multiple units) differing in certain arrangements. The three test campaigns were conducted between June 2007 and March 2008. In each campaign, some 20 experienced train drivers from several countries performed railway operation scenarios, including unexpected incidents. Their feedback was collected using research questionnaires which formed the basis for the test analysis. Though the number of test drivers was limited, these test campaigns represented the most thoroughgoing analysis at European level of the driver's workplace to date.

The results of the test campaigns served as a basis for a European standard (EN) on the layout of drivers' cabs. The project partners from manufacturers and operators are committed to establishing a working group under the umbrella of the CEN TC256 in order to transfer the results of EUCAB into a European standard.



Figure 9: EUCAB/EUPAX mock-up at the InnoTrans trade fair (Berlin, September 2006)

2.3.2 EUPAX

The EUPAX workstream focussed on the international harmonisation of MMIs for passengers and train staff, including improved access for persons with reduced mobility (PRMs). Adopting a similar approach to that of EUCAB, the EUPAX team developed FRS and SyRS for those sub-systems constituting MMIs, such as:

- the door portal, including the door opening and closing devices
- passenger information systems (PIS)
- safety alarm systems (SAS)
- PRM-relevant devices (toilets, guidance devices, etc.)

These specifications were refined and detailed in expert discussions between manufacturers, operators and experts, and used to create a 1:1 scale functional mock-up in September 2006. Following the public presentation at the InnoTrans fair, comprehensive testing was conducted on all the mock-up devices between autumn 2006 and spring 2007. Based on an expert evaluation, the MMI features of the mock-up were assessed by wheelchair users, blind and visually impaired and deaf people, parents with small children as well as a reference group made up of people without any such impairments (see fig. 10).

The test results served to further improve the EUPAX-related FRS and SyRS. Detailed discussion of the knowledge gained enabled the EUPAX team to agree on recommendations to improve existing standards, e.g. EN 14752 "Railway applications – bodyside entrance systems":

- Door opening devices: circular activation field with diameter min. 40 mm.
- Door opening devices: to be placed on the outside door leaf.
- Emergency module/devices: labelling (also tactile) by self-explanatory pictogrammes
- Visual information: the character size defined in TSI PRM should be enlarged (doubled) for vital information (emergencies).

Additionally, the EUPAX test results clearly identified areas requiring further investigation for future revisions of EN 14752 and the TSI PRM:

- Vestibule and gaps
- Ramps, steps and handrails
- Door opening devices (topics: tactile information, interior layout)
- Emergency module/devices (one single module vs. separate devices located at around the same height near wheelchair door; details of tactile information)
- Toilet for PRMs (see fig. 11)

Corresponding follow-up project activities are under preparation, using the thorough basis established by the EUPAX tests.



Figure 10: EUPAX – Evaluation of entrance conditions



Figure 11: EUPAX – Toilet designed to meet the requirements of wheelchair users

2.3.3 EUCOUPLER

The main objective of the EUCOUPLER workstream was to specify an interoperable data link between trains and locomotives. It represents an important milestone towards the vision of “open coupling” – seamless connection between trains from different operators all over Europe.

The EUCOUPLER team worked closely alongside the MODCONTROL sub-project in a series of steps to define a comprehensive set of communication services for future implementation. The project output consists of a migration concept comprising four “packs”:

- Pack 1 with a conventional cable as per UIC leaflet 558 (“Remote control and data cable”) for locomotives and reversibility, including WTB (wired train bus).
- Pack 2 with an automatic coupler (type 10) incorporating the UIC 558 train-lines, WTB with adapted data transmission and Ethernet pre-cabling (maintenance network possible).
- Pack 3 with an automatic coupler (type 10) facilitating the transition of some existing train-lines (UIC 558) into a new secure link protocol; Ethernet technology is included and used for maintenance and data transmission.
- Pack 4 with an automatic or conventional coupler: a considerable portion of data is transferred to Ethernet technology with a secure link protocol; hardware train-lines are minimised.

The specification work in EUCOUPLER resulted in a change request to UIC leaflet 556 “Information transmission in the train (train-bus)”, which was submitted to UIC in spring 2008 for a corresponding revision of that standard.

Parallel to the MODLINK workstreams, a generic and transparent Life Cycle Cost (LCC) assessment tool was developed as a uniformly-accepted instrument to assess the cost implications of introducing modular sub-systems and devices. This cost-benefit analysis tool is available to be used in other European procurements in the pre-competition phase.

2.4. MODCONTROL

The MODCONTROL sub-project led by ALSTOM was responsible for standardising the Train Control and Monitoring System (TCMS) functions and the interfaces between the TCMS and the train sub-systems within the MODTRAIN project.

To achieve this goal, the first step was to draw up a detailed FBS (Functional Breakdown Structure) of rolling stock functions, including TCMS functions, and a detailed PBS (Product Breakdown Structure) of the sub-systems and outputs of the rolling stock system. The breakdown was performed up to level 5.

The FBS provided a list of train functions and a short definition of each function. This FBS is used when referring to one of the train’s functions. Some of these functions can be standardised for all product lines or a specific product line such as “locomotives” or “high speed trains”. A standardised FBS was also needed before any steps could be made towards standardising the train’s functions. This FBS was to be standardised at European level.

The nine level-1 functions are:

- Carry and protect passengers, train crew and payload
- Provide passengers, train crew and load with appropriate conditions
- Enable access and loading
- Connect vehicles and consists
- Supply energy
- Accelerate, maintain speed, brake and stop
- Provide train communication, monitoring and control
- Support and guide the train on the track
- Integrate the vehicle into the railway system as a whole

An FRS (Functional Requirement Specification) was drawn up by the four sub-project teams for each train function. The requirements were drawn from the Technical Specifications for Interoperability, IEC standards, European Standards, UIC leaflets, Operator Requirement Specifications for locomotives and high speed trains and significant company-specific project specifications for system integration such as AGC, Prima locomotive, Velaro or the E402B locomotive. The requirements are undergoing harmonisation in order to ensure their consistency, approval by the three major operators SNCF, DB, and Trenitalia, and their optimum impact on train costs. The requirements are stored in a database in a requirement-engineering tool called Requisite Pro, produced by IBM. The tool is available on a UNIFE server. 45 members of MODTRAIN have the rights to enter or modify the data in the database.

At present, around 5 000 requirements are stored in the database (figure 12).

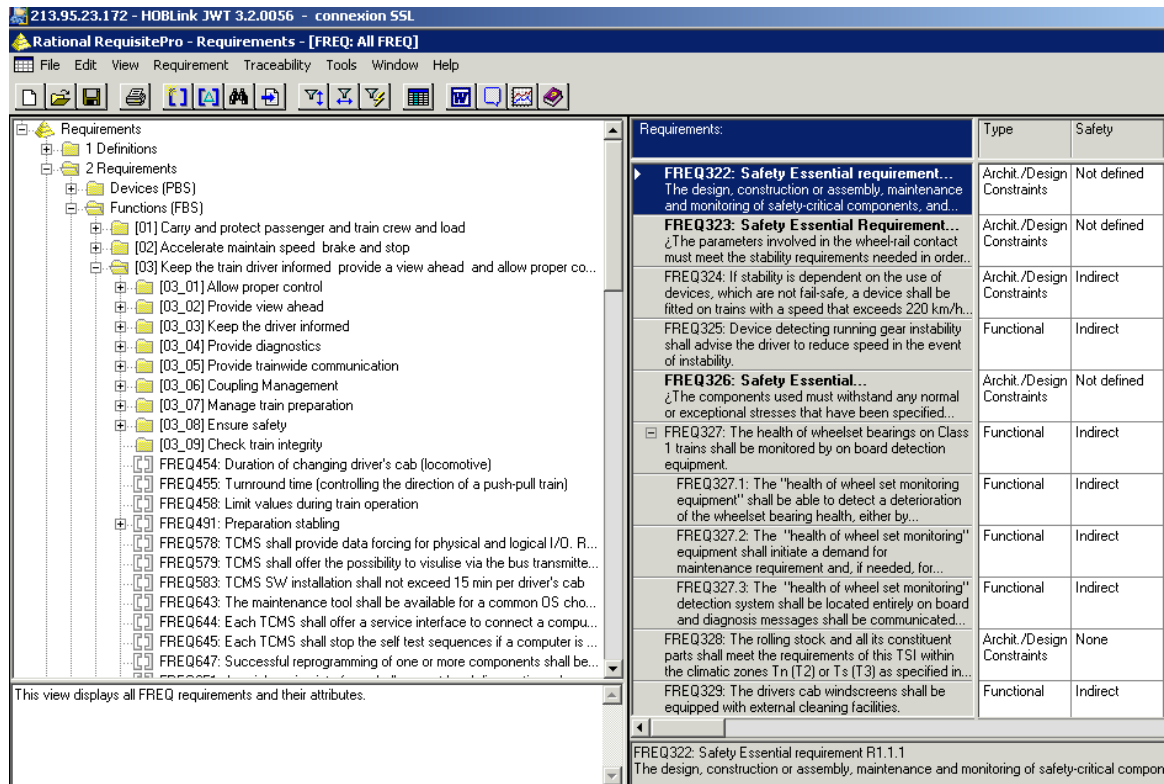


Figure 12: Requisite Pro database

In the second phase of the project it is planned to define standardised interfaces between the TCMS and the following train sub-systems:

- Doors
- HVAC (Heating, Ventilation and Air Conditioning)
- PIS (Passenger Information System)
- Diagnosis
- Auxiliary
- Battery
- Pantograph
- Bogie
- Traction
- Brake (as part of MOBDRAKE)

Each interface will be described in an FIS (Functional Interface Specification) integrating UML diagrams into its definitions. The objective is to create profiles that will be independent of the network with which the sub-system is linked.

A potential version of the HVAC FIS is depicted below (figure 13).

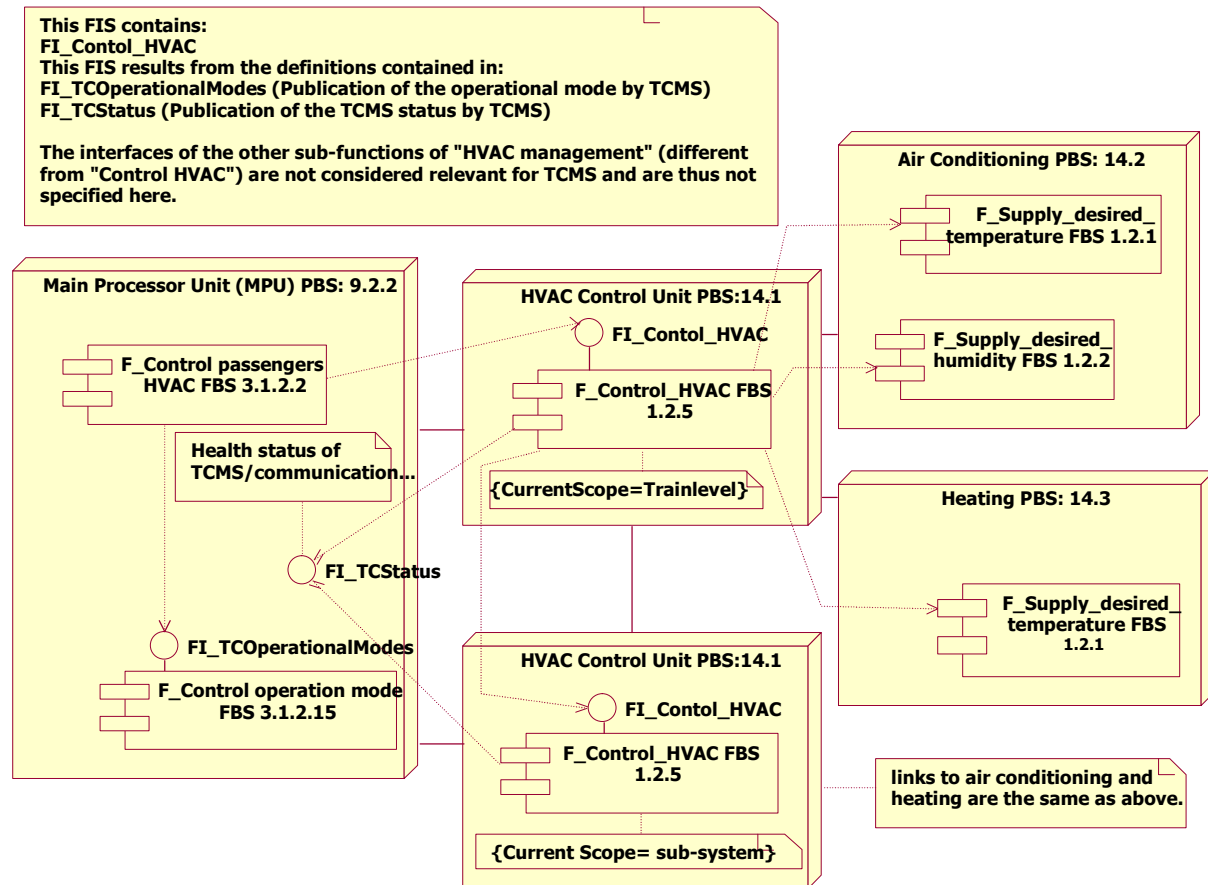


Figure 13: Potential version of the HVAC FIS

In order to replicate the interface definitions for each sub-system, a model simulating the interface will be generated from the UML diagrams used to specify the interface. A model of the TCMS component and a model of the sub-system will be added to this model. A number of tests will be run using fixed sets of train consist data. Each set of train consist data will contain the data relevant to the specific interface test to be executed. An Ethernet network will be used for the demonstration. Rapid prototyping will be possible. The various models are to be incorporated into the MODLINK hardware mock-ups.

The MODCONTROL Safety Group, a team of safety experts from ALSTOM, Bombardier and Siemens, carried out a qualitative safety analysis of the train functions and FBS sub-functions, including Hazard Identification, Risk Analysis and Hazard Control Analysis (figure 14). The impact on safety was assessed for each function. Safety requirements were expressed for those instances where a function had a direct or indirect impact on safety.

The aim and purpose of the MODCONTROL Safety Group was to:

- Take the FBS provided by the MODCONTROL system group and determine which functions were safety-critical, and which of those were affected by the TCMS.
- Determine the associated boundary hazard(s), hazard cause(s), barrier(s) and accident(s) for all functions both safety-critical and affected by the TCMS.
- Draw qualitative fault trees to illustrate the relationships between the boundary hazard(s), hazard cause(s), barrier(s) and accident(s).
- Write a guidance document describing the process of analysis adopted by the MODCONTROL Safety Group, including the preceding stages and a method for determining the safety integrity objectives and assigning them to the TCMS elements.

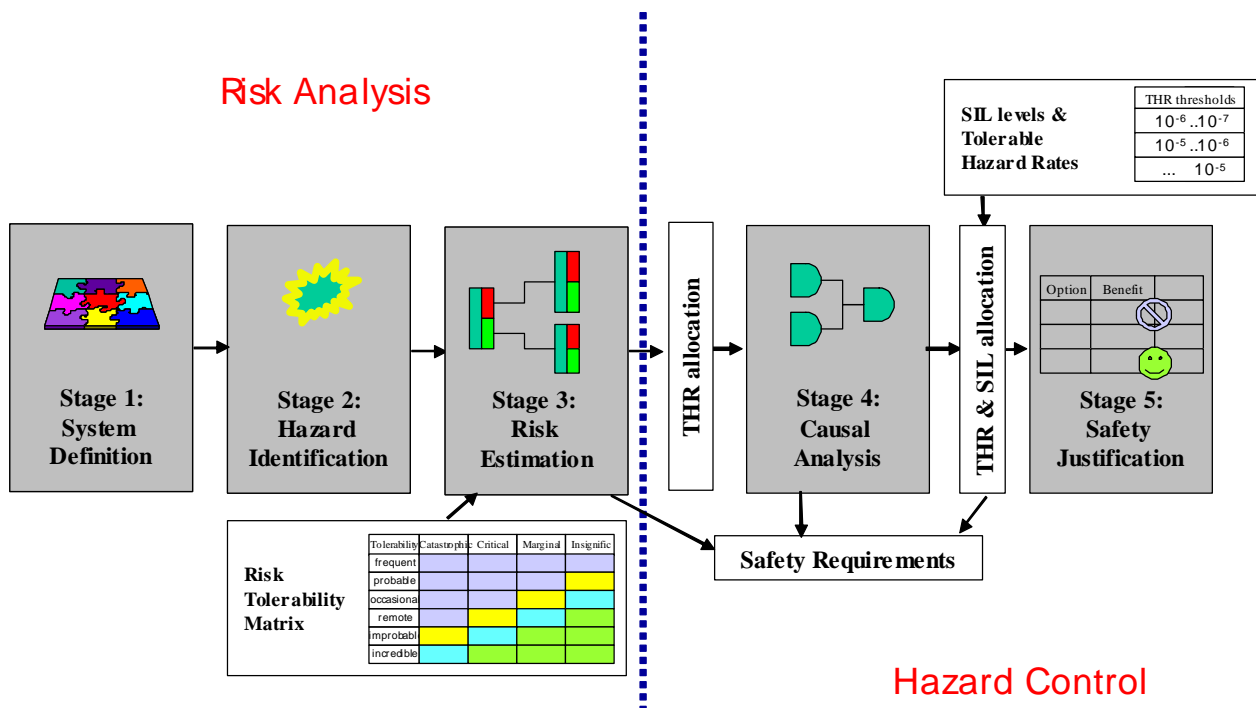


Figure 14: Risk Analysis and Hazard Control

Fault tree analyses were performed for each hazard (figure 15):

- Excessive heating source near inflammable train parts
- Train track guidance impaired or lost
- Vehicle movements beyond dynamic envelopes
- Excessive jerk
- Unintentional braking
- Impaired braking
- Accessible hazardous voltage
- Insufficient ventilation or air conditioning
- Internal passenger door spontaneously opens
- Internal passenger door fails to open
- Steps or ramp fail to withdraw
- Steps or ramp fail to deploy
- Exterior passenger door fails to deploy
- Exterior passenger door fails to close
- Spontaneous closing of an exterior passenger door
- Spontaneous opening of an exterior passenger door
- Interference with trackside equipment or other train
- Incapacitated driver not detected

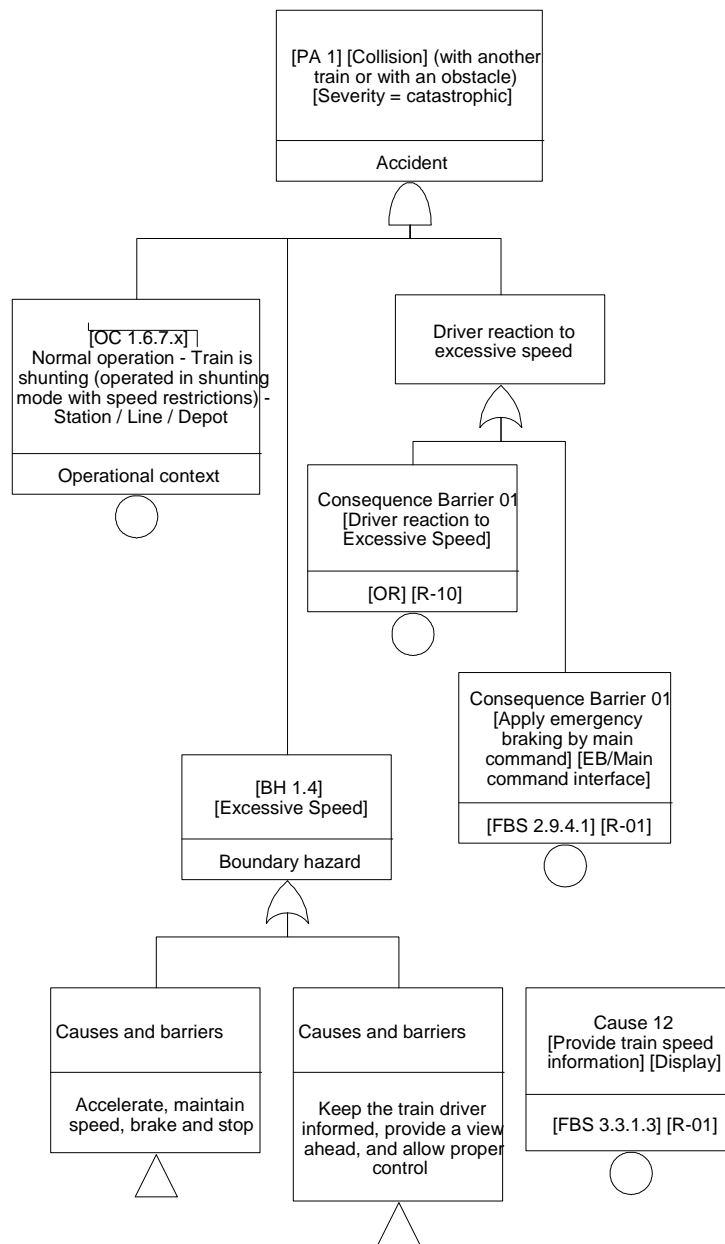


Figure 15: Fault tree analysis

The MODCONTROL sub-project is proud of the effective partnership developed between its participants and the members of the other sub-projects, which enabled a real breakthrough to be made in the process of standardising the functions and sub-systems interfaces of the European high speed trains and locomotives of the future.

2.5. MODBRAKE

The European MODBRAKE project was set up as an extension of the MODTRAIN project in order to consider as an entire sub-system the brake system of high speed trains and universal locomotives with speeds of over 190km/h. The aims of the MODBRAKE project therefore ensued from the need to address brake issues from a systems point of view, which was not fully covered by the MODTRAIN project. MODBRAKE is a Specific Targeted Research Project (STREP) and contributes to the Sustainable Surface Transport Priority of FP 6. MODBRAKE addresses brake-related issues of interoperability and standardisation in line with the MODTRAIN structure of sub-systems. Three large railway undertakings (DB, SNCF, Trenitalia), four major vehicle manufacturers (Alstom, AnsaldoBreda, Bombardier, Siemens), the two biggest brake suppliers (Knorr-Bremse, Faiveley), two associations (UIC, UNIFE), three research centres (Tabor, Polito, TUB) and a project management specialist (ALMA) were actively involved in the project. The project, the technical stewardship of which was provided by Knorr-Bremse, officially started in June 2006 and is scheduled to last 30 months.

MODBRAKE investigates the potential for standardisation of braking system modules at all levels of the vehicle architecture. Additionally, MODBRAKE aims to derive frameworks and drafts for future standards, functional specifications, interface definitions and test specifications. The results in terms of design principles and interface definitions will be demonstrated by functional prototypes. Further, MODBRAKE will issue proposals for standardisation to be submitted to the European standardisation bodies CEN and CENELEC.

MODBRAKE thus contributes to a common understanding of brake-related requirements and will complement standardisation activities in the rail sphere. In so doing, MODBRAKE facilitates the practical implementation of pan-European interoperability in rail systems, which is one of the key objectives of EU transport policy.

The main objectives of the MODBRAKE project are:

- Specification of the brake system modules, considering modularisation at different levels of the rolling stock architecture
- Elaboration of functional concepts for brake modules, including their interfaces with other sub-systems
- Specification of validation/assessment and maintenance processes in accordance with inspection/test criteria for safety and reliability
- Development/improvement of a tool for the evaluation of brake modules' life-cycle costs
- Submission of proposals to standardisation bodies concerning brake requirements for future standardisation or standards to be updated
- Exemplary implementation of specification results for brake control and bogie equipment, application of the test specifications.

Initial achievements

The majority of the workload in the first project phase was dedicated to compiling the Functional Requirements Specifications (FRS) and Operational Requirements Specifications (ORS) for the MODBRAKE-related modules and sub-systems. These were drawn up in a process of ongoing cooperation between manufacturers and operators with the support of research institutes.

The technical part of MODBRAKE concerned mainly the following tasks:

- Analysis of the existing standards and regulations and identification of brake-related functional, performance and interface requirements as a precondition for the drafting of the FRS/System Requirement Specifications (SyRS)
- Review of the ORS 612 series via detailed, regular discussions between the MODBRAKE manufacturer partners, in close coordination with the UNIFE "Brakes" Topical Group
- Contribution to the DIN/MODTRAIN/MODBRAKE Functional Breakdown Structure (FBS).

Moreover, manufacturers and operators agreed on a set of brake-related components/modules to be further standardised within the scope of MODBRAKE.