# MODURBAN

## FP6 Project: IP 516380

## EC Contract n°: TIP4-CT-2005-516380

# WP26 - MANAGEMENT

## – DELIVERABLE REPORT –

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## Approvals

| | Name | Company | Date | Visa |
|---|---|---|---|---|
| | | | | |
| *Technical Management Committee* | B. VON WULLERSTORFF<br>G. POITRASSON-RIVIERE<br>D. DIMMER<br>G. LEGOFF<br>L. LINDQVIST<br>U. HENNING / A. PRICE<br>M. NOCK<br>JP RICHARD / D. COINEAU<br>Y. AMSLER<br>C. GOUTORBE | UNIFE<br>ALSTOM<br>THALES<br>ANSALDO STS<br>BOMBARDIER<br>SIEMENS<br>KNORR BREMSE<br>RATP<br>UITP<br>ALMA | 14/05/09 | OK |
| *Coordinator* | B. VON WULLERSTORFF | UNIFE | 14/05/09 | OK |
| *Quality Manager* | B. VON WULLERSTORFF<br>C. GOUTORBE | UNIFE<br>ALMA | 14/05/09 | OK |

## Document history

| Revision | Date | Modification | Author |
|---|---|---|---|
| V0 | 18/03/2009 | Template provided to Subprojects leaders for completion | ALMA |
| V1 | 29/04/2009 | First version including inputs from SP leaders | SP Leaders |
| V2 | 13/05/2009 | Second version consolidating all input | ALMA |
| V3 | 14/05/2009 | Final version including coordinator's revisions and input | UNIFE / ALMA |

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# 1. Project objectives and main achievements

## 1.1. Origin and objectives of the project

Interoperability is a key talking point for urban rail operators today, just as much as it is for Europe's main line railways. But unlike the main lines, which are concerned about cross-border operation of passenger and freight trains, interoperability in the urban sector is all about technical compatibility between existing lines and network extensions.
This is particularly critical at a time of rapid technical development, notably the emergence of communications-based train control systems with a much higher level of on-board intelligence. For example, operators want to be able to take a trainset from one line and run it on another within the same network.

A worldwide survey launched by UITP in 2005 found that:

- 80% of operators saw an advantage in ensuring interoperability in their network;
- 60% saw an advantage of having independence between on-board and wayside equipment;
- 40% were prepared to support higher initial costs to achieve interoperability;
- 60% were interested in participating in a group applying common specifications during tendering.

As a result, it was felt that a system wide approach was needed for command, control and signalling systems; communications; access and passenger information systems; and energy saving technology. Consequently, the *Modular Urban Guided Rail System* project, or MODURBAN for short, was launched at the beginning of 2005 and was officially completed in March 2009. Intended to develop common functional specifications for operators and a common technical architecture for manufacturers, MODURBAN is a joint R&D project funded 50% by market stakeholders and 50% by the European Commission under the 6th Framework Programme for Research & Development.

## 1.2. Consortium and structure

MODURBAN was the first project of its kind — a Europe-wide joint precompetitive R&D project. It brings together all the major rail industry systems integrators and suppliers, European urban rail operators and universities in a consortium with 39 members. Project management is being handled by Unife, the European association for the railway supply industry. The project's general objectives are fully in line with Unife's mission to promote greater standardisation and the harmonisation of interfaces.

As shown in figure 1 below, the project was divided into six sub-projects:

- Mod-OnBoard, dealing with onboard subsystems, led by Alstom Transport;
- Mod-WaySide, looking at wayside subsystems, led by Ansaldo STS;
- MOD-Comm, examining the data communication subsystem, led by Thales RSS;
- MOD-Access, focusing on passenger and access related subsystems, led by Knorr-Bremse;
- MOD-Energy to assess energy savings-related subsystems, led by Siemens;
- and finally MOD-System, which adopted a complete system approach for functional and technical specifications and global risk assessment, led by RATP.

There was also a Users Group, which consisted of operators not direct members of the consortium. Their input and feedback on key deliverables has been important in order to validate and disseminate some of the results.

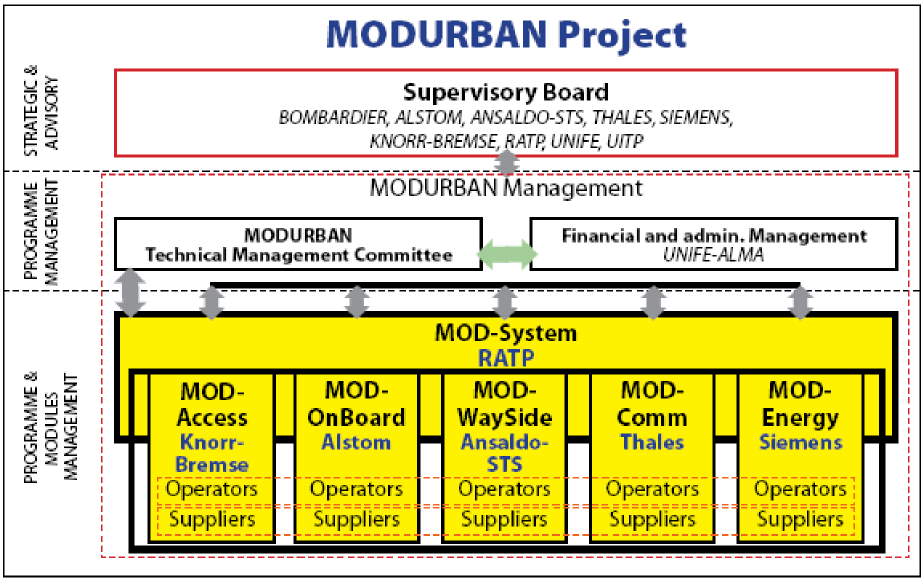



*Figure 1: Structure of the MODURBAN project*

## 1.3. Ambitions and outcomes

The consortium's goal is to achieve a reduction in the overall cost of buying and operating a rail system, through the development of a specification — reflecting world best practice — which fulfils the operators' essential requirements.

*The MODURBAN Function Requirement Specifications*
The major result after almost four years is the Functional Requirement Specifications. Known as D80, this document encapsulates the recommended functional and performance requirements for command, control and train management systems for urban rail applications. It is fully endorsed by operators and by the entire MODURBAN consortium.

Based on many years of operating and manufacturing experience, the FRS includes a complete set of 'ready-to-use' requirements. It covers networks ranging from manually driven trains to fully driverless operation. A common system core ensures a seamless upgrade route from one level of automation to the next, right up to unattended train operation. The basic operational characteristics outlined in the FRS include:

- general requirements;
- functional requirements;
- grades of automation;
- interoperability requirements;
- principles for degraded operation;
- system performance requirements.

The functional specifications contain a complete set of functions and requirements based on 'mandatory functions' and 'optional functions' according to the Grades of Automation. These cover functions for train operation, including rules to ensure safe movement of trains, functions for operation management and supervision, as well as system performance criteria, for example those related to passenger exchange (boarding and alighting at stations).

The benefits are crystal clear: the assurance of having a comprehensive set of requirements, derived from the wealth of experience gained by major players, which represents a state-of-the-art performance specification with no surprises.
Tenders issued in conformity with the MODURBAN FRS will avoid unreasonable or unforeseeable risk and cost factors, and should thereby help to reduce the costs associated with bespoke development and project implementation.

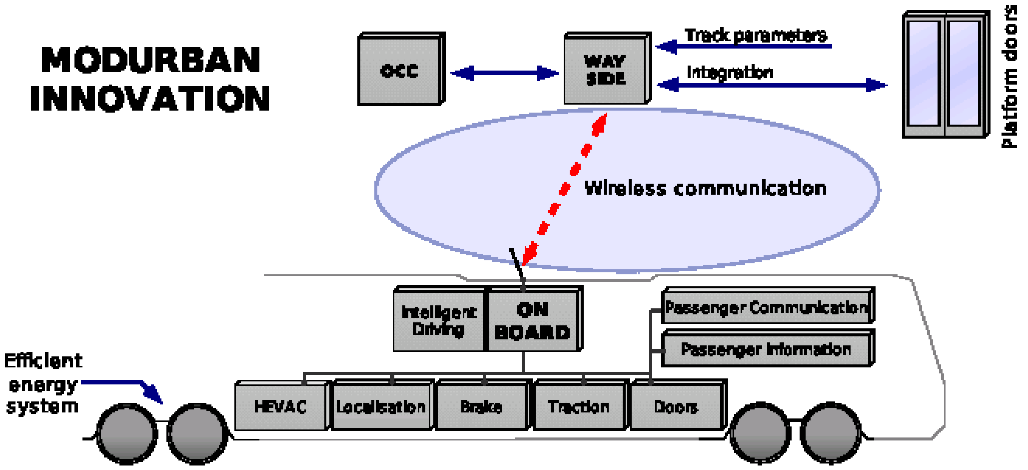



***Figure 2: MODURBAN has looked at innovation in every sector of the urban rail mode***

Whereas a commonly agreed FRS presents clear benefits for operators, it is perhaps less obvious what it offers for the suppliers.

If the operators are working to a commonly agreed FRS, the manufacturers will be able to anticipate their requirements much better. The tendering and bidding process should be greatly simplified by following a widely-known and clearly defined method of structuring requirements. There should also be a reduction in the risks traditionally associated with the implementation of new technology. And finally, the common standards will encourage much greater development of standard off-the-shelf modular technology to meet specific market needs.
In turn, the FRS should ease the compliance assessment procedures by using emerging safety concepts. For command, control and signalling applications, the suppliers have worked out a common system architecture based on a limited number of options. This is a first — but important — step towards standardisation and the harmonisation of interfaces which will also open up the market and encourage diversification and competition between suppliers.

Furthermore, the different levels of automation and options covered by the common system architecture will encourage the development and implementation of both software and hardware on a modular basis.
All in all, the use of jointly-agreed requirements will help to clarify the roles and responsibilities between the operators and their suppliers — and that is REAL progress.

*The MODURBAN Common system architecture*
Under MODURBAN's common system architecture, functions are allocated to a system or subsystem level. However, it has to be noted that the participating suppliers did not manage to agree on categorising all of the functions, so some requirements are therefore met through a limited set of well-defined options. This common architecture also clearly identifies the interchangeable modules and the required level of specification for the interfaces, whether functional or fully-descriptive.

The main advantage of this common architecture is that it is applicable to all system configurations with or without existing interlockings, with or without secondary train detection, and it is capable of accommodating different levels of automation.
One of MODURBAN's most innovative achievements is the definition of a commonly agreed 'Fault-tolerant Data Communication System' which is transparent to the train control system. Today almost all urban rail operators have a multitude of data and voice communication systems, both fixed link and radio. Each of these has a dedicated role — for example one to deal with train control and signalling, another with video surveillance, another for voice communications, and so on. However, none of them are interoperable and they cannot talk to one another.

Progress has been made in this area because MODURBAN, and the MODComm sub-project in particular, has defined a system architecture where one communications network can support all of these disparate applications using international standards (IEEE 802.3) for interfaces and Internet Protocol for message routing. This will enable operators to procure and install data communication equipment from different suppliers, thanks to the specifications requiring interchangeable modules.

Other achievements include the Intelligent Driving concept, which addresses the problems of variation in train parameters with time, and the deviation of the train parameters (such as braking and traction capacities and reaction times) outside the normal range, across an entire fleet. Intelligent Driving is able, for example, to learn the train parameters and verify their deviation, and adjust the key parameters where necessary in order to compensate for any observed deviations in train performance.

With regards to passenger information systems, MODURBAN has delivered an overview of this equipment and its functions, together with a comparison of the principal European products. It has also defined Passenger Information System interfaces to other MODURBAN subsystems, and provided a useful overview of regulations in the EU member states in the field of video surveillance, as well as a functional description of the system architecture.

With a much greater awareness of energy consumption and the need for energy saving, there has been considerable interest in MODURBAN's work in this field. A number of energy saving models have been reviewed and validated against real-life data. One specific result has been the development of a prototype lightweight interior grab rail.

The MODURBAN project culminated with the final presentation and tests of some of its technologies on Metro de Madrid Line 9, on December 16th and 17th 2008. Using a dedicated MODURBAN train, it showcased successfully:

- the Intelligent Driving concept;
- operation of the Interchangeable Data Communication System;
- onboard and wayside equipment for passenger information and video systems;
- the use of lightweight materials, notably the new grab rails.


***Figure 3: the MODURBAN test train of Metro Madrid***

## 2. Detailed subproject outcomes

### 2.1. MODONBOARD

#### 2.1.1. Objectives and structure

The aim of the MODONBOARD subproject was to focus on the onboard MODURBAN modules, defining a standard architecture and the corresponding interfaces, developing the Intelligent Driving approach, analysing the possibility to reuse ERTMS components within the transit domain and testing the different design elements defined through a mock-up.

To reach these objectives, the subproject was split into workpackages:

- WP1 – Onboard ATP
- WP2 – Intelligent driving
- WP3 – ERTMS reuse

#### 2.1.2. WP1 – Onboard ATP

The objectives of this workpackage are:

- Define the design of the onboard ATP subsystem.
- Define the corresponding interfaces for interoperability.

The onboard ATP subsystem is split into interoperable and specific modules. The main modules are:

- The Carborne Controller (CC, computer implementing the ATP and ATO functions)
- The train HMI (interface to the driver)
- The SPTS (Spot transmission subsystem)

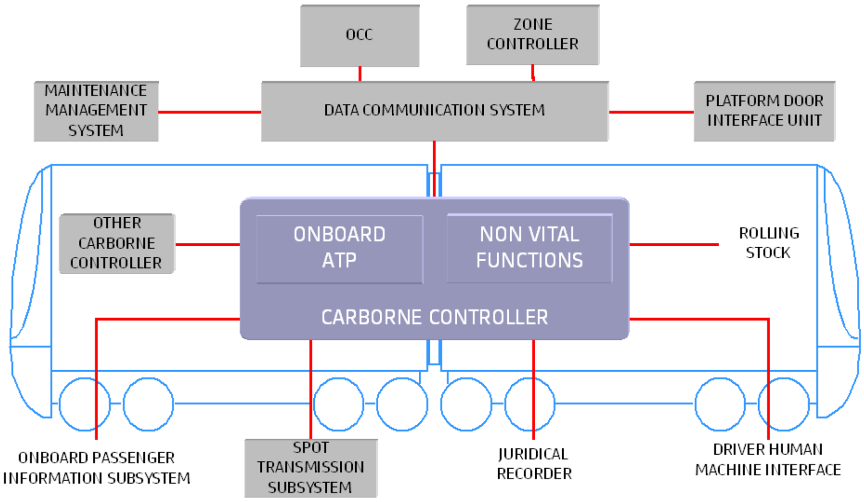



***Figure 4***

The outcome was the elaboration of the ATP Onboard specification and interfaces with MOD-Wayside.

#### 2.1.3. WP2 – Intelligent Driving

Objective

Intelligent Driving addresses the problem of variation of train parameters over time and discrepancies on train parameters of a whole fleet. It automatically adapts the train control system to these variations in order to optimise each train performance.

The train parameters to be considered are the braking capability, the traction capability, train reaction times, etc.

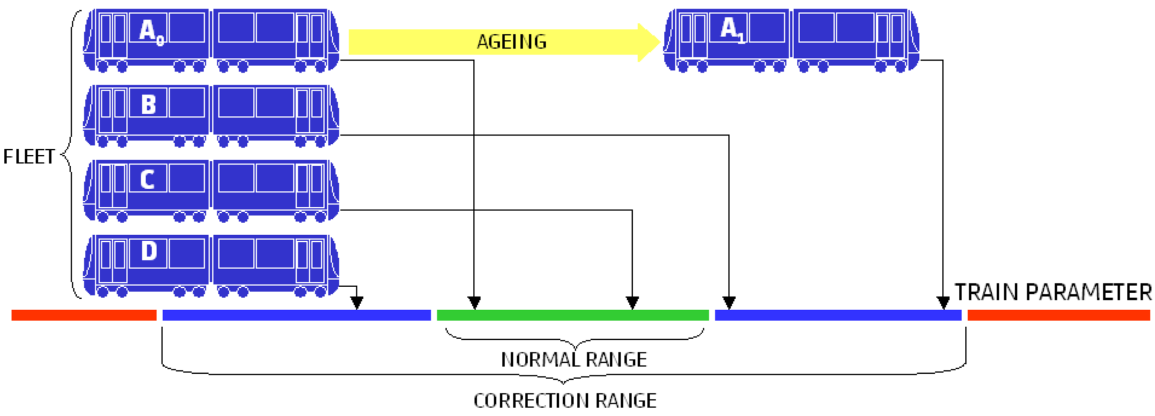



***Figure 5***

Principle

A model of the dynamic behaviour of the train taking into account parameters such as braking/traction capability, reaction times, braking behaviour (electrical and mechanical), has been specified and implemented using MathLab.

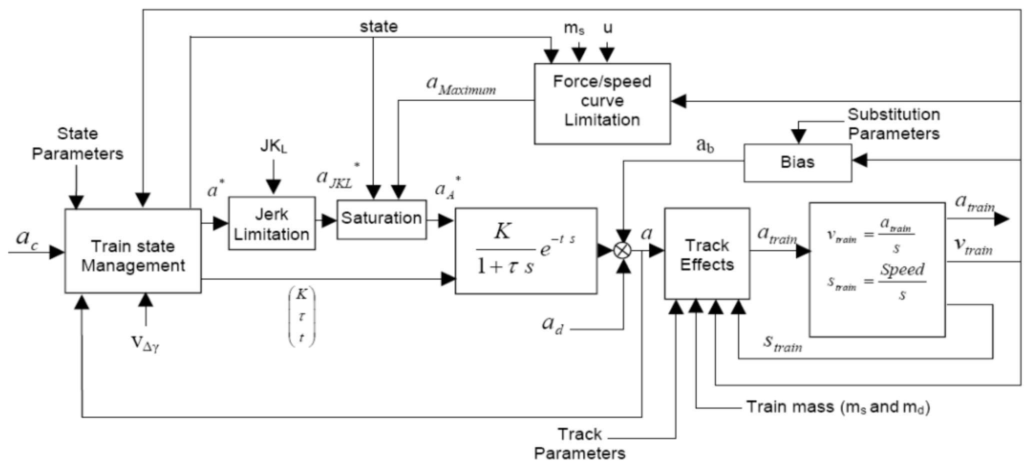


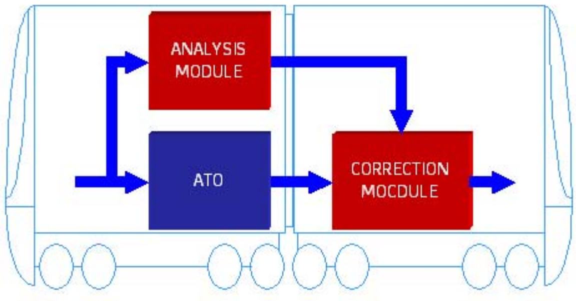

***Figure 6***

In result, this model of the dynamic behaviour of the train has been elaborated.

Implementation

For this purpose, Intelligent Driving:

1. learns the train parameters and verifies their deviation
2. Sends alarms in order to warn operation staff about the train achievable performances in the point of view of ATC
3. Adjusts adaptive parameters if necessary in order to tackle with the deviation observed on the train



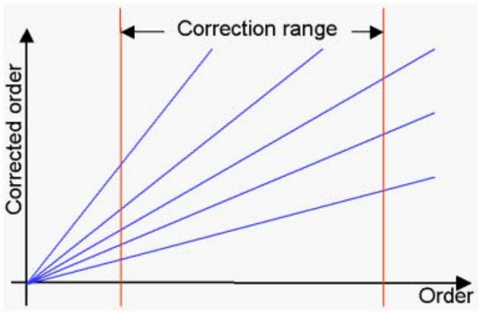




***Figure 7***

The Intelligent Driving system addresses slow parameter degradation, adjusting parameters and informing operation and maintenance staff of the degradation.

The following drawing shows the degradation of the braking capability of the train, the Intelligent Driving adaptation of the braking order (in green) ensuring an acceptable stopping accuracy when the braking capability decreases and the alarm generation when the degradation is too important and requires a maintenance action (in red).

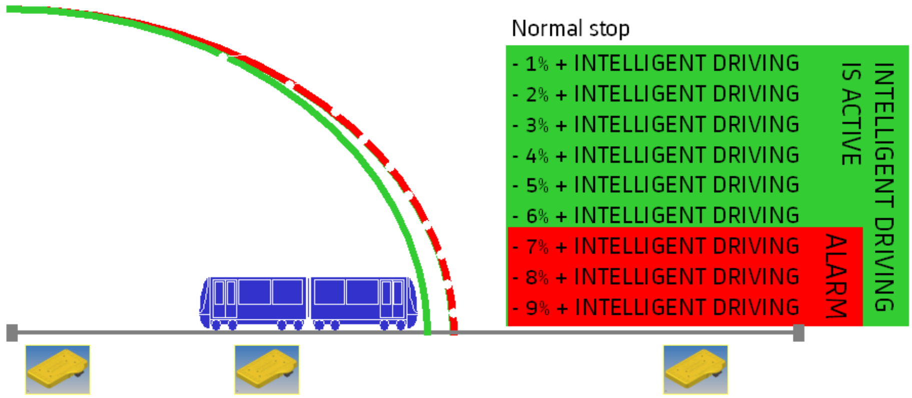



***Figure 8***

<u>Tests Principle</u>
The Intelligent Driving tests are based on automatic correction of braking commands from the ATO to the train braking system.

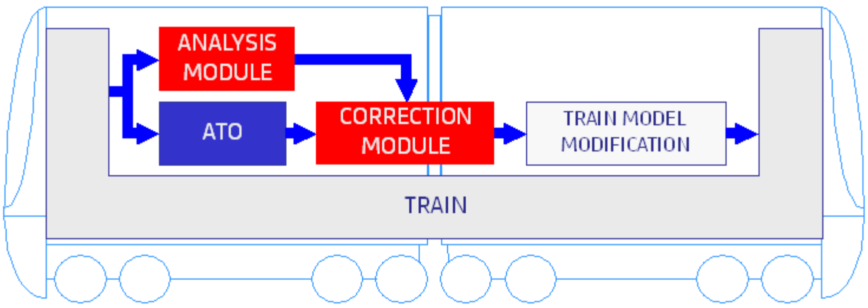



***Figure 9***

This automatic correction is defined by the ANALYSIS MODULE and performed by the CORRECTION MODULE.

In order to test this automatic correction, the braking capability of the train seen by the ATO is reduced.
This reduction is implemented by the modification of the braking order (TRAIN MODEL MODIFICATION) delivered to the train.

As a result, the test principles were also described in a comprehensive document.

Tests Scenario
The braking capacity of the train is reduced (TRAIN MODEL MODIFICATION)
The System shall progressively adapt the ATO order to ensure the train stopping accuracy
Depending on the reactivity parameter of the system, the accuracy shall be recovered after 10 to 15 runs.

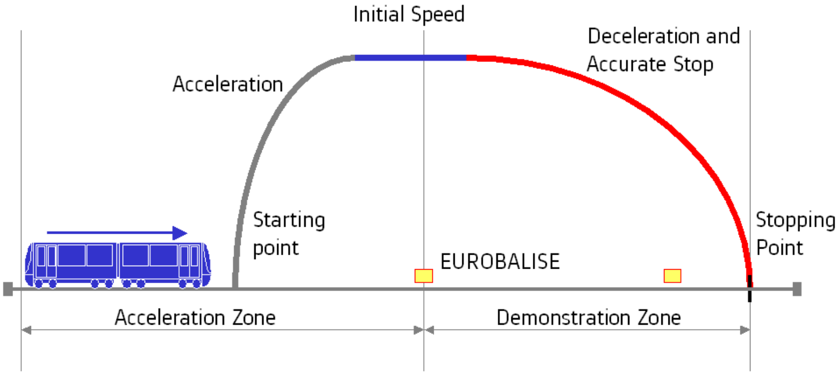



***Figure 10***

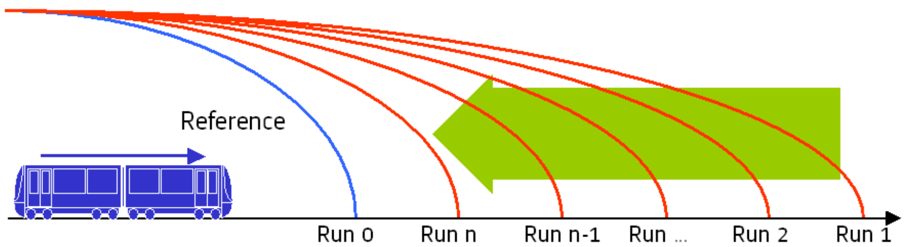



***Figure 11***

The tests were held in Madrid on the 16th of December 2008 with around 130 people witnessing its success. The results demonstrated the adequacy of the Intelligent Driving principle to the requirements and are detailed in a separate document.
The following picture shows the Human Machine interface of the Intelligent Driving system prototype for the tests.

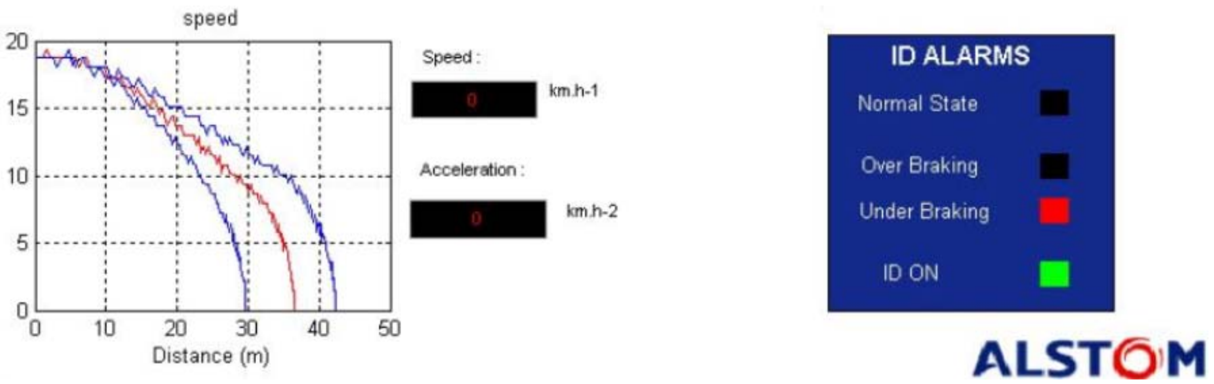
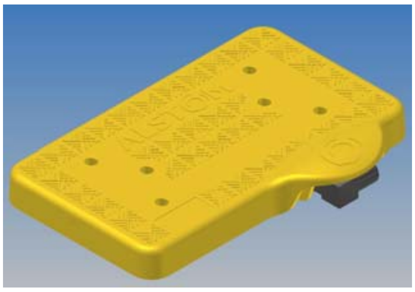



***Figure 12***

The braking curves are recorded. Indicators show the detection of the braking degradation and the implementation of the Intelligent Driving adaptation.

### 2.1.4. <u>WP3 – ERTMS</u>

The aim of this workpackage was to analyse the possibility to reuse some ERTMS modules, and, if necessary, to propose some adaptations in order to fit with the mass transit constraints.



Due to the differences between the domains of application between ERTMS (mainly mainline environment) and MODURBAN (urban rail environment), the scope of this workpackage has been reduced to the spot transmission.

The mission became to analyse the reusability of the EUROBALISE spot transmission. In particular, the accuracy of the relocalization (top loc) has been considered.

A document detailing the Transit version of the EUROBALISE specifications provides the conclusion of the workpackage on the EUROBALISE reuse by MODURBAN.

## 2.2. MODWAYSIDE

### 2.2.1. Scope and objectives

The objective of MODWAYSIDE was to define the Operational Control Centre (OCC) and its interfaces to wayside equipment, as well as the ATP modeling, including Interlocking and wayside objects management (ATP Wayside) through an optimisation of the system objects description.

In the view of giving a flexible integration for new systems and encourage a convergence in the process for partial or complete line renewal, MODWAYSIDE allows operators and suppliers to agree on a common interface definition, in order to significantly reduce the development cost, by developing:

- A common base of specifications;
- A formal standard languages for object description;
- A set of “graphical objects” for OCC Man Machine Interface design.

It must be mentioned that the cost of signaling renewal or extension of line is, in many cases, increased by the adaptation of suppliers’ product to specific interfaces and local or national functions. The cost impact of these adaptations is estimated at 40% of the overall price of the Wayside system, split as follows:

- System design : 20%
- Hardware interfaces : 10%
- Tool adaptation : 10%

Furthermore, considering the schedule to complete a real life signalling urban project, a significant impact may be also expected; indeed the system activities and the data configuration will be drastically shortened and the duration reduced by half of an overall project. So typical design and installation work can be reduced from 36 months to 18 months.

The major innovation is therefore to define a common specification standard for interchangeable module (IM) interfaces, through standard languages in order to formalize operators’ needs and suppliers’ data inputs, in the following fields: Man Machine Interface, geographical track layout and associated interlocking data description.

Infrastructure data modeling is crucial to improve the information flow between various work processes. A common data model facilitates the interoperability of different systems, provided by different suppliers. Sharing of the same representation of the network allows cost reduction of signalling renewal or line extension. A Standard data models can be used to:

- Significantly improve the availability and consistency of data set across different software systems;
- Integrate data across various disciplines;
- Exchange information between various partners.

### 2.2.2. Impact on industry sector

The result expected from MODURBAN MODWAYSIDE is the validation of the principle of an open standard definition:

- ➢ Data preparation: To reduce the time schedule, the tests effort and the safety assessment, both in terms of data description as in term of tools and languages: Automatic data generation for database and interfaces, from the specification up to the validation.
- ➢ OCC HMI: Demonstrate that the definition of a standard interface (FFFIS) may adapt to the use of several existing technologies, at low cost and with a limited impact on the entire signalling system operation.

### 2.2.3. Work breakdown

The work was divided into two workpackages:

- <u>Development of the intelligent formal data preparation (in the scope of WP6 as shown here below)</u>: selection and validation of a formal language, describing the physical configuration and the geographical layout, as well as the physical or logical object introduced for signalling purpose. Such a model aims to standardize data exchange between the prescriber and provider (operator and industry), according to the following process:

    - To list the data mandatory for the ATP system configuration.
    - To deal with the data-entry level of the "Data Preparation process".
    - To provide a set of "Basic" data, needed to generate "final" data:
        - "Basic" data refers to the entered data.
        - "Final" data is the one used by ATP and refers to the "Data preparation/ATP IM" interface.
    - To cover all the data that the interchangeable functions usually use.
    - The basic data is classified independently of:
        - Who (operator or supplier) provides the data,
        - How the "Final" data is stored and managed.

- <u>Definition of the interchangeable module OCC preparation (in the scope of WP7 as shown here below)</u>: today, the interface between the ATP and the OCC is specific to each application, which induces time and cost of adaptation. The aim is to define a set of basic functions, a command control interface and a standardized process of data preparation for OCC HMI, so as to validate the principle of an open standard interface with the ZC, CC, and PDIU.

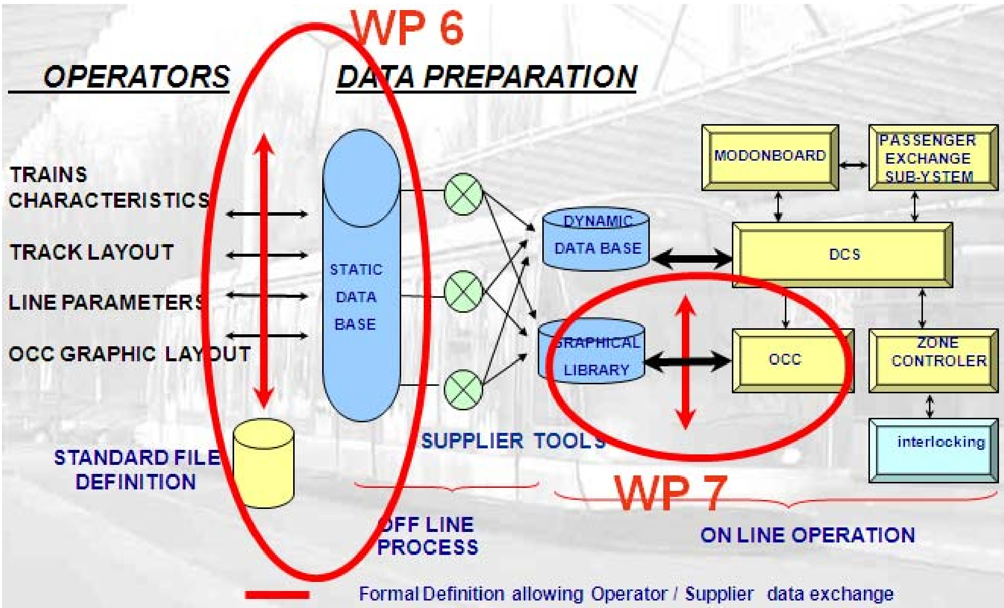



***Figure 13: the ModWayside approach***

### 2.2.4. <u>Achievements</u>

Modwayside tried to reuse as much as possible existing European standards, like RailML from Euro-interlocking, according to the following steps:

- ✓ Data list for ATP: Functional analysis of the requirements, with codification of the object through a formal descriptor;
- ✓ Validation report: Integration of the data list object within the RailML model, with extension when necessary;
- ✓ OCC Object library: Analysis of the Functional requirements in term of supervision (Control & command), with identification of standard HMI objects

- <u>Development of the intelligent formal data preparation</u>:
    - Data list for ATP and associated process definition: The work package has been concluded with the production of a functional static data model derived from the final guidelines for func-

tional requirements. This work led to partners agreement on a set of recommendations and proposals for data preparation and functional modeling (with inputs from Euro Interlocking)

The document (internally called D25) identifies the data structure, as needed to describe the MODURBAN system static interfaces.

**❑ D25 – Data list for ATP and associated process definition:**

***Intelligent formal data preparation:***

- ✓ ***Class_Name;***
- ✓ ***Attribute***
- ✓ ***Instance;***
- ✓ ***User;***
- ✓ ***Vital;***
- ✓ ***Origin;***
- ✓ ***Comment;***

**Formalised set of Static Data allowing to model any transportation network based on:**

- *Track infrastructure layout;*
- *Train characteristics;*
- *Wayside signalling equipment description;*
- *Interlocking logical objects*

| | Class_name |
|---|---|
| 5 | Static Guideway Database |
| 10 | Data |
| 15 | Network |
| 20 | Line |
| 25 | Line section |
| 30 | Line_Section_Table |
| 35 | Track |
| 45 | Track segment |
| 50 | Adjacent segment |
| 55 | Segment_Table |
| 60 | Track Element |
| 65 | Gradient |
| 70 | Station |
| 75 | Platform |
| 80 | Platform screen doors |
| 85 | Station_PSD |
| 90 | End of track |
| 95 | Train Detection Element |
| 100 | Point |
| 105 | Route Protection Element |
| 110 | Power section |
| 115 | Key Lock |
| 120 | Transponder |
| 125 | Detector |
| | ……….. |

- o Tools benchmarking report, including formal language selection: Definition of a process and agreement on pre selected tools that have been benchmarked
- o Final validation report and test result on selected formal tools: This model has been the subject of a successful implementation under Xml (By extension of the RailML model).This modelisation has been proved to be pertinent with respect to a real track data set (Metro de Madrid Test track). Additional presentation of the model has been made using UML Class Diagram

The purpose of the D28 document was to propose a MODURBAN data model and to conclude about the pertinence of the tools bench marking, which led to the choice of RailML

**❑ D28 – Benchmark final report and tests results on selected format :**

***RailML is pertinent:***

***The railML® contains subschemas for Three main areas:***

- ✓ *Infrastructure;*
- ✓ *Timetable;*
- ✓ *Rolling stock;*

**Schema organization**

Several XSD schema files ,logically organized:

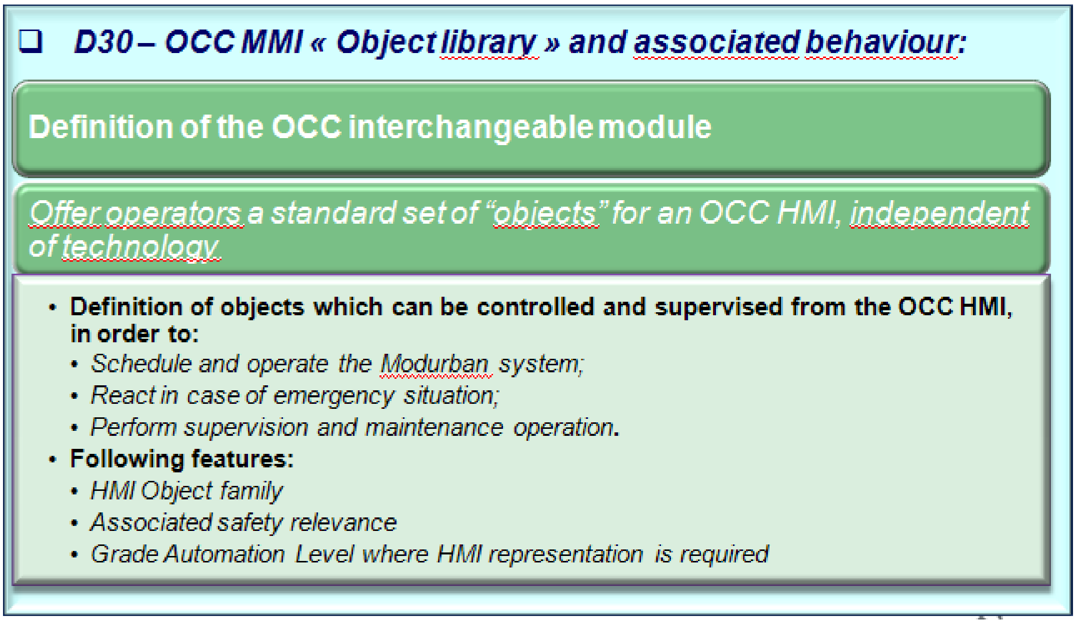
- ✓ MODInfrastructure.xsd: Define the infrastructure elements;
- ✓ MODCommon.xsd: Contains all data commonly used by most elements;
- ✓ MODInterlocking.xsd: Contains all the interlocking elements (Not dealt with in railML);
- ✓ MODUnits.xsd: Define the units.
- ✓ MOD Sub Systems.xsd: Defines the MODURBAN sub systems elements;

**Model reusability:**

- ✓ Items reused, extended or added to the railML model to match with the MODURBAN specificities;
- ✓ According to the [D25] document structure, the number of items identified is:

| **Track layout:** | **12 items identified** | % |
|---|---|---|
| railML matching: | 4 items | 33% |
| Extension needed: | 2 items | 17% |
| Added to model: | 5 items | 42% |
| **Track side equipment:** | **6 items identified** | |
| railML matching: | 3 items | 50% |
| Extension needed: | 1 item | 17% |
| Added to model: | 2 items | 33% |
| **Rolling stock:** | **1 item identified** | |
| railML matching: | 1 item | 100% |
| **ATP Device:** | **21 items identified** | |
| Added to model: | 21 items | 100% |

- <u>OCC MMI "Object library" and associated behaviour</u>: Definition of the interchangeable module OCC and its formal interface with the ZC or CC.




### 2.2.5. <u>Next steps</u>

The work provides a sufficient consensus among the various industrial, institutional or operators on the use of data modeling language as RAIL_ML. In the same way, a consensus was reached on the description of standard objects library describing the OCC interface, ready to be customized through screens and animated graphical icons, according to the needs of each operator in terms of imagery or Man machine dialogue.

The MODURBAN Integrated Project offered an exceptional opportunity to promote technical standards that are to be introduced so as to achieve interchangeable and cost-effective performing systems, paving the way to the preparation of a draft standard by CEN/CENELEC.

## 2.3. MODCOMM

### 2.3.1 Objectives

The objectives of the MODCOMM subproject were as follows:

- To identify the communication requirements for future urban rail systems. This included identifying what applications would be supported, along with their functional, performance, reliability and maintenance requirements.
- To define a fault tolerant architecture for the communication system, based on the requirements of the applications, and determine if a single network could support all applications.
- Specification of the interface between the DCS and user applications, both onboard and wayside
- Identification of appropriate wireless communication technology. This included an evaluation of existing wireless system, and a study of developing wireless standards.

Select and test three wireless technologies. Testing would be in the lab and in the field.

MODCOMM was divided into four work packages. The work packages were performed serially, with subsequent work packages not starting until the previous one was completed. The work packages are described in the following sections.

### 2.3.2 WP9

WP9 had three deliverables:

- Data Communication System Functional Requirements Specification (FRS)
- Data Communication System Performance, Reliability and Maintainability Requirements
- Data Communication System Architecture

At the beginning of the work on the DCS Functional Requirements, a survey was created for all operators who were partners in MODURBAN or part of the user's group. In the questionnaire operators were invited to provide their current and future data communications needs. This information, plus the knowledge of the partners in WP9, provided the basis for the development of the FRS.

DCS Functional Requirements Specification

The goal of the FRS was to define all communication needs for an urban transit system. This included providing a communication link to equipment on the train, on the wayside, and at the OCC. It did not include communication within the OCC, or internal onboard communication to equipment such as traction and brakes.

The FRS determined that the DCS would only support the transmission of digitized data, and applications that use the Internet Protocol (IP). The applications that will be supported are shown in the DCS Context Diagram, below.

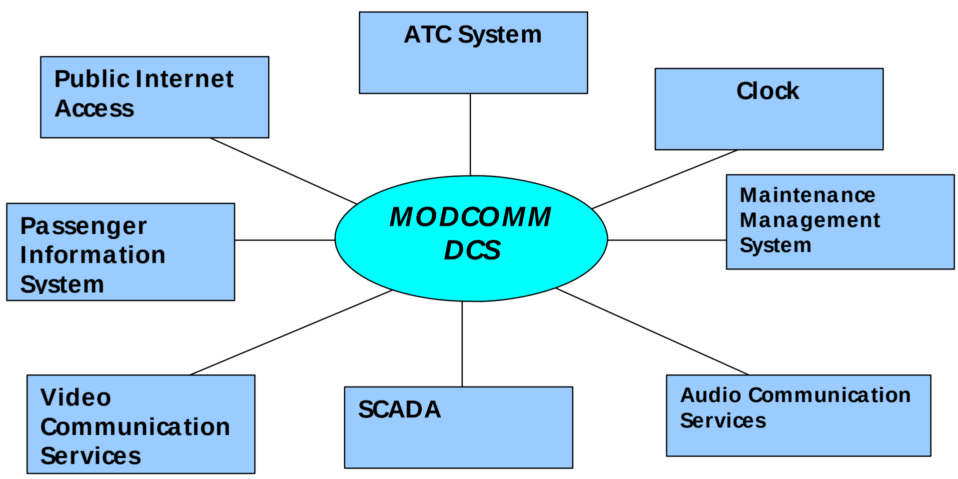



*Figure 14: DCS Context diagram*

The independence of the DCS from the applications which use it, is a fundamental principle that was established. In conjunction with the work of MODSYSTEM WP22, WP9 established that the DCS must be functionally independent of the applications that use it. The DCS will support OSI layers 1, 2, and 3 as shown in the following figure. The Internet Protocol is considered part of layer 3.

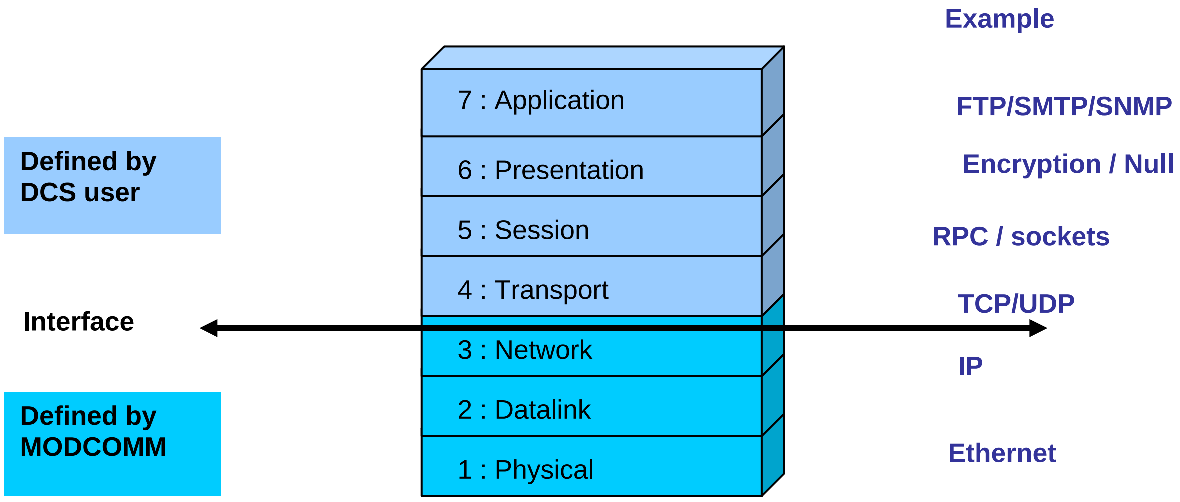



***Figure 15: DCS Scope***

There was no attempt to establish a standard for the wireless air gap. This was not a goal of the project, primarily due to the speed of innovation in this area.

<u>DCS Performance, Reliability, and Maintainability Requirements</u>
The DCS Performance, Reliability, and Maintainability Requirements provided the quantitative performance requirements that a DCS must meet. This dealt primarily with the latency and bandwidth requirements of each application, along with its tolerance for lost or corrupted messages.

In addition specific requirements for reliability and maintainability were defined.

<u>DCS System Architecture</u>
The goal for the DCS System Architecture was to take into account the DCS Function Requirements, and Performance, Reliability and Maintainability requirements to develop an architecture for a single communication system, that can replace the multiple communication systems currently in use in transit systems today. An emphasis was placed on fault tolerance.

Figure 16 below shows the proposed architecture. Trusted applications are applications which require the full protection specified in EN50129-2, and thus can only be connected to the DCS via a Security Gateway. Train control is an example of a trusted application. Untrusted applications do not require such protection and can be connected to the DCS at any point.

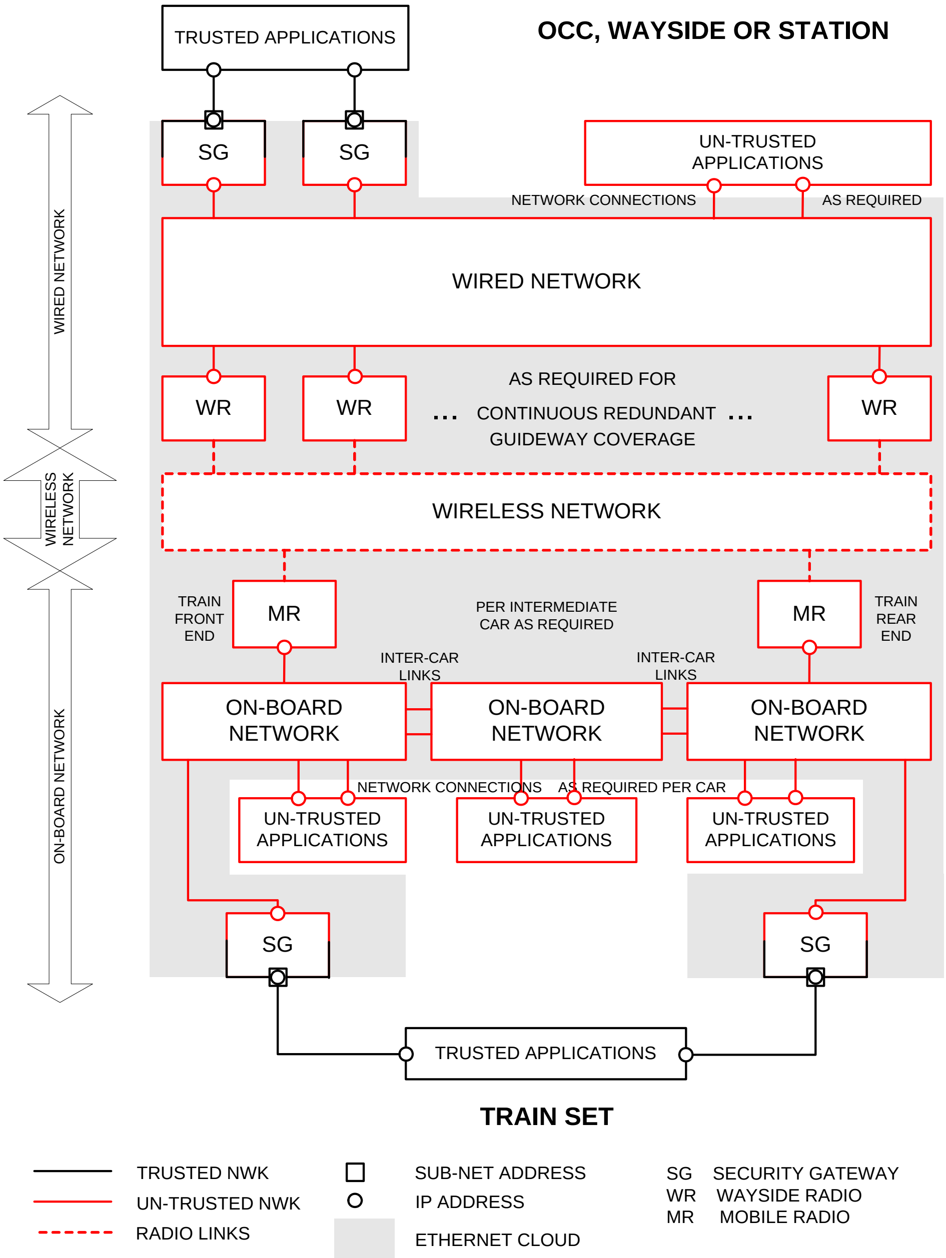



*Figure 16: DCS Architecture*

### 2.3.3 WP10

WP 10 had a single deliverable entitled “MODURBAN DCS Interface and User’s Guide’.

This document specified the interface between the DCS and applications that use it. The interface was agreed to be either the first three layers of the OSI model as shown in Figure 15, or the first two layers. The difference is whether the DCS needs to provide layer 3 switching and in particular priority of messages. It was agreed that layer 2 switching would be acceptable in applications where message priority between applications was not required.

The physical and datalink layers were specified as Ethernet and IEEE 802.2. The network layer was specified as the Internet Protocol (IP).

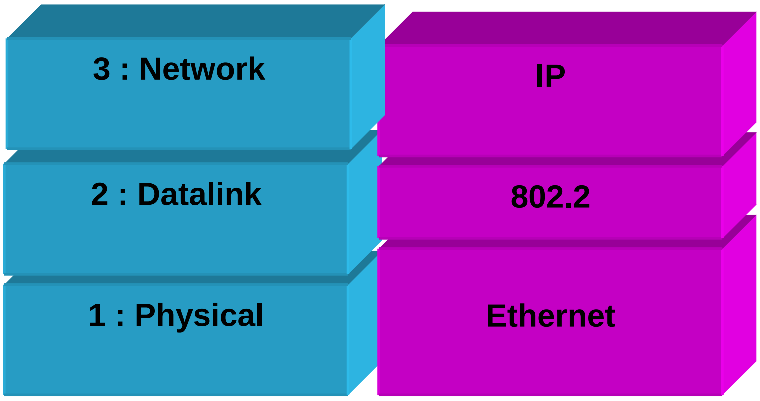



***Figure 17: DCS Logical Interface***

The user's guide provided recommendations with regards to an addressing plan, a profile of upper communication layers, and a profile of applications.

### 2.3.4 <u>WP11</u>

The goal of WP 11 was to evaluate wireless technology. This began with an identification of existing wireless communication systems, and an evaluation of whether they met the requirements for the MODURBAN DCS. Six classes of wireless technology were reviewed:

- Cellular
- Wireless LAN, such as IEEE 802.11
- WMAN such as IEEE 802.16
- UWB & WPAN including IEEE 802.15
- WWAN
- Proprietary Systems.

In addition some other technologies such as MIMO, and multi-homing were analysed.

The technologies were evaluated according to the following criteria:

- Waveform and its resistance to interference
- Access method
- Diversity
- Bit rate controllability
- Mobility management
- Multi-flow management
- Mobile routing techniques.

The second phase of WP 11 was to evaluate evolving standards for future technology. The following standards were reviewed:

- Ultra Wide Band
- IEEE 802.20: Mobile Broadband Wireless Access
- IEEE 802.22: Wireless Regional Area Networks (WRAN)
- Continuous Air Interface for Long & Medium Range (CALM)
- IEEE 802.21: Multi-vector and multi-homing
- Vertical mobility

The final action for WP 11 was to determine which technologies should be tested by WP12. The following technologies were chosen:

- IEEE 802.11h
- IEEE 802.16e
- IEEE 802.11a & IEEE 802.11g combined

### 2.3.5 WP12

WP 12 dealt with all aspects of testing the three wireless technologies selected by WP11. It had four deliverables:

- MODCOMM Demo Definition
- DCS Equipment Design
- Lab Test Report
- Field Test Report

The MODCOMM demo definition defined the tests that would be run in the lab and the field. A common set of tests was developed for the lab testing, so a comparison could be made of the results.

The DCS Equipment Design provided a detailed design for each of the three technologies being tested in the field. This included the network design, and wayside radio placement. The figure below provides a sample of one of the network designs for the test track.

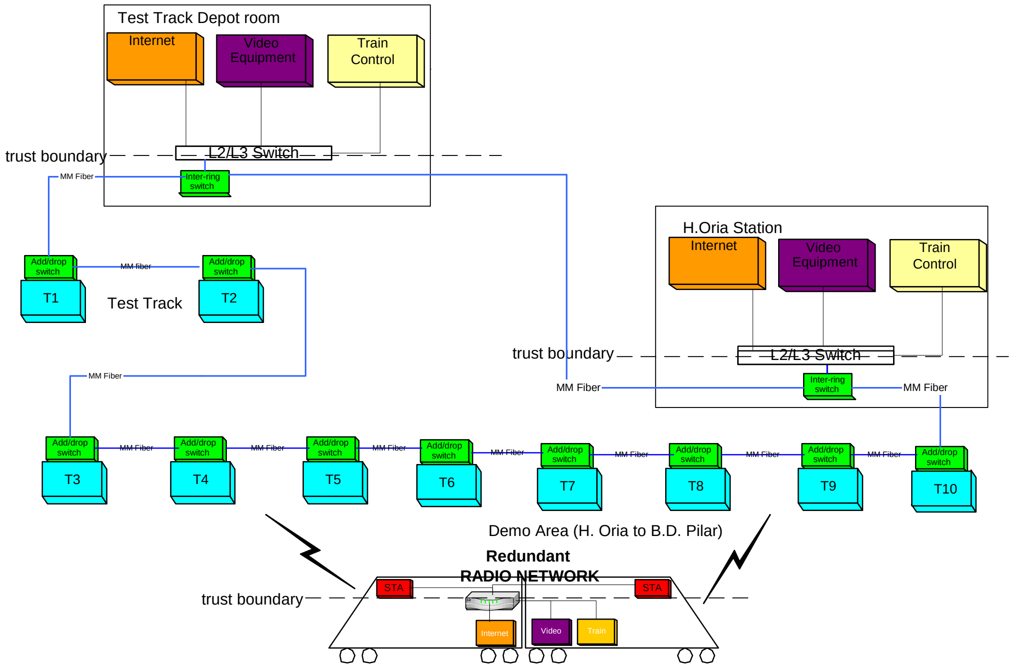



***Figure 18: Field Test Network Design (Example)***

The three suppliers involved in the field testing performed a radio survey of the test track approximately six months before testing, and determined the optimal locations for their wayside radio equipment. Equipment procurement and manufacturing took place during a four month period and was completed two months prior to the start of testing. Installation of the equipment on the Metro Madrid test site took approximately two months.

Only two of the technologies could be tested in the lab. The IEEE 802.16e equipment was not available prior to the field test so this eliminated the opportunity for a lab test. The other two technologies were successfully tested in the lab. In order to confirm that common functionality was achieved by both DCSs, RATP personnel visited both partners, Siemens and Thales, to observe the testing.

Field testing took place during the period from October 1 to December 16, 2008. During this time each DCS was tested with an ATC (Automatic Train Control) simulator. The fact that all three systems could successfully transport the data from the simulator demonstrated that the DCS had been successfully implemented as an interchangeable module.

Due to logistical issues, it was decided that only two of the three DCS would be used during the ModUrban demonstration on December 16. The Siemens (IEEE 802.11a and IEEE 802.11g) and Elta

(IEEE 802.16e) systems were used during a successful demonstration which used the ATC simulator and video equipment from MODACCESS to show that multiple applications could be simultaneously supported.

Following the completed of the field tests, the Lab Test Report, and Field Test Report documents were finalized and released prior to the end of the project.

#### 2.3.6 Conclusion

MODCOMM completed all of its original goals.

Definition of the functional and performance requirements for the DCS provides the basis for the deployment of networks which will support all of the applications required by urban transit operators.

Agreement on the interface between the DCS and the applications that use it was one of the most significant accomplishments of MODURBAN. This allowed the DCS to be defined as an interoperable subsystem within the MODURBAN system architecture, and will allow for separate procurement by transit operators.

The MODCOMM partners were successful in testing three different wireless technologies and DCS designs during this period. Review of test results for the different technologies that were used, will allow suppliers to make a decision as to the viability of using these technologies for future urban transit projects.

## 2.4. MODACCESS

The MODACCESS subproject addressed three different categories of issues. Despite being independent, all three are contributing to the same aim: improving both the ease and the quality (safety, cost …) of the access function for the passenger, the operator and the industrial access systems supplier. The results of this subproject intended to facilitate the upgrade of an existing network/line and the specification for a new system. Therefore using the MODACCESS results in both cases will be:

- more likely to happen (reduced uncertainty)
- cheaper to implement (reduced engineering and testing)
- cheaper to operate (less energy, reduced number of disruptions)
- providing a better and more comfortable service to the passenger

Benefits from MODACCESS are both direct and indirect. Direct, by stabilising modules functionalities and interfaces, and avoiding a significant share of the redesigning for each project.
Indirect, by removing uncertainty risks which operators have to face when installing, for example, platform screen doors on a network or a single line: by calling on well defined and established MODACCESS specifications for the functions and the modules, the operator will be much keener to move ahead and enjoy the benefits in terms of comfort, safety and savings (energy, less disruption of traffic…).

Hence the benefits for the customer are:

- Support and guidance for tender process
- Overview of state of the art of access systems
- Comprehensive set of requirements deriving from years of experience of major operators and industry players
- High degree of interoperability as integral part of MODURBAN system architecture

Physically, the subproject aimed to design, develop and validate (Figure 19):

- System Critical Passenger Information and Interaction (WP13)
- Door Systems especially on Automatic Operated Trains (WP14)
- Platform Screen Doors (WP15)

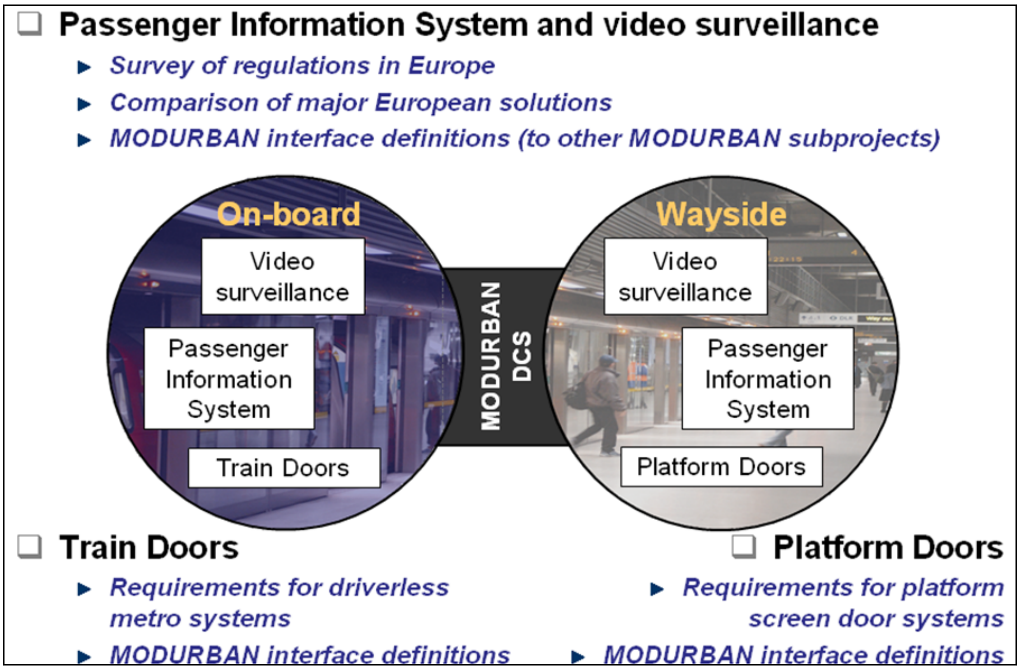



*Figure 19: content of ModAccess*

### 2.4.1. Passenger Information Systems

The research tasks associated with this workpackage especially focused on warning cases like degraded mode and emergencies and means to monitor situations (e.g. video surveillance) and on the definition of the products and the functions of passenger information systems in order to provide information easy to understand for all EU citizens.

For all these aspects, specifications for standardised functional requirements for the following purposes have been issued:

- Defining the functionality of HMI devices on board
- Standardising the requirements for content and kind of information to the passenger such as: acoustic information and displayed information (formats, colours, languages, graphics)
- Obtain common interfaces for the access modules. The work lined up with the other MODURBAN subprojects (esp. MODCOMM and MODSYSTEM) to guarantee a high integration and standardisation level for every device.

The MODACCESS tests that were performed in Madrid on December 16th 2008 simulated the functionalities of passenger information systems (Figure 20).

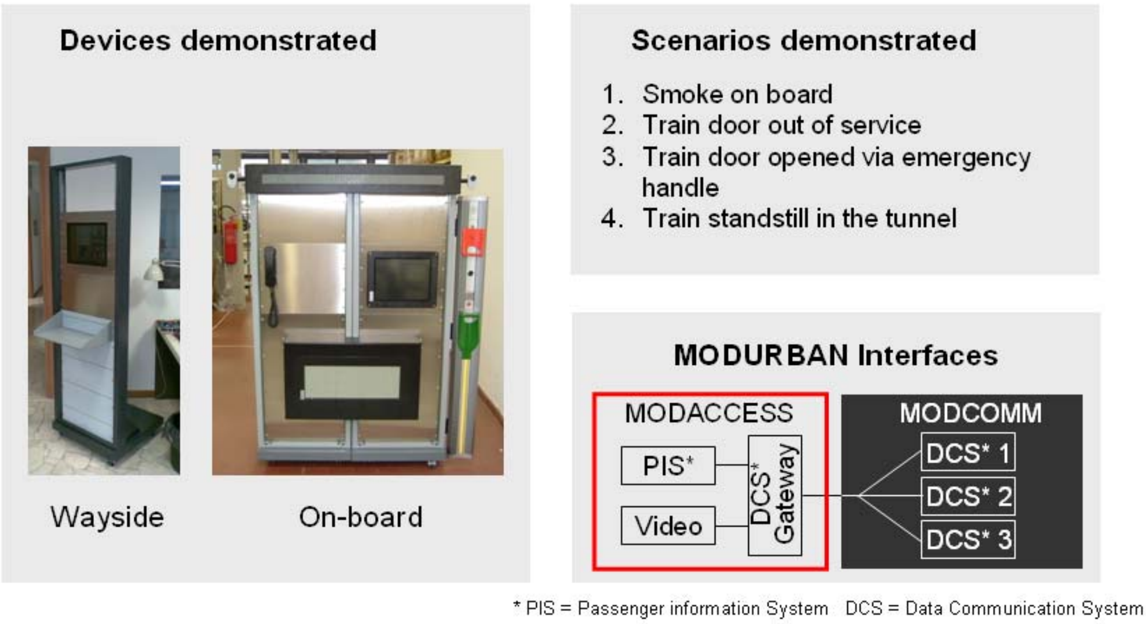



***Figure 20: setup for Metro Madrid tests***

As test scenarios, "smoke on board", "train door out of service", "train door opened via emergency handle" and "train standstill in the tunnel" have been chosen as examples for the various situations analysed in MODACCESS.

The test layout has been chosen in the way that it was possible to select the driving configuration in relation to the functionalities of the Passenger Information System (PIS) directly on the on-board PIS Server through a touch screen monitor.
The onboard demonstrator system consisted of: video surveillance system, passenger information system and the interface with the DCS (Figure 21, right). The wayside demonstrator (Figure 21, left) consisted of an OCC emulator, platform video surveillance system, passenger information system and the interface with the MODURBAN DCS, a part of the MODCOMM work.


***Figure 21: MODACCESS wayside and onboard test equipment***

### 2.4.2. Door Systems

The work in this workpackage dealt with the doors functions especially in the absence of personnel on board. Interfaces have been defined for the door system in order to connect it to the MODURBAN system. One outstanding part of this interface definition is the description of the interface to the platform door system. The specifications summarised in guidelines, function analysis with special consideration of the system safety accompanies the work done.

### 2.4.3. Platform Doors

Platform doors, becoming a “natural element” of many urban rail systems, as they are drastically reducing accidents or simply incidents associated with people falling or wandering on the tracks.

The scope and targets reached in this workpackage are:

- For the definition of the scope of standardised requirements for PDs:

The main outcome is the definition of a MODURBAN specific specification facilitating a standard PD functional and non-functional requirement specification that can be used by MODURBAN partners throughout Europe to aide in reducing procurement costs.

- For the determination of PD installation requirements and interfaces for new and existing stations:

This work systematically provides a general description of the main elements of a PD system. Important topics for the planning and the physical installation of PDs onto new or existing platforms are discussed. Also the main electrical interface requirements as well as the interface to the MODURBAN control system are described and discussed. These results shall support operators in the planning phase for PD installations. Standardised specifications and procedures will reduce planning efforts, procurement costs and installation times.

### 2.4.4. Available documents

MODACCESS has consequently produced a number of documents which are available for download and the use at both operators and industry:

***For Passenger Information Systems***

- Requirements, list of relevant standards
- Report on optimised application of video and audio surveillance systems
- Information for passengers in driverless trains (incl. comparison of major European metro systems)
- Passenger related functions in degraded modes, passenger emergency functions
- Interface specification, evaluation of requirements and safety requirements

***For Train Doors***

- Guidelines/definition of requirements for door systems on innovative driverless urban transport systems
- Guidelines/definition of requirements to interface with platform doors

***For Platform Doors***

- Functional and non functional requirements, including interfaces
- Definition of installation requirements for new & existing stations

## 2.5. MODENERGY

The main subjects of this subproject are:

- Develop and offer practical and affordable solutions (robust for the every day use) to decrease the energy consumption of urban railway systems.
- Increasing the energy efficiency of several subsystems - Efficient Air-conditioning system; Energy recovery systems; Train Control - and by identifying future potential savings (use of light-weight materials).
- System approach that will be taken with an objective of a Return on Investment within 5 years with a validation process for appropriateness of the developments made by other networks.

### 2.5.1. WP16: Prescription for HEVAC's in a total system approach and development of advanced optimisation software to reduce consumption in a Metro System

This workpackage started with the specification of the main energy contributions to the air temperature, together with the physical modelling of the heat exchange inside the Metro System. The aim was to develop a software tool in order to estimate the impact of the use of the HEVAC inside the whole system. A special interest was focused on the comfort of passengers by estimating the temperature in the tunnel and stations, under humidity conditions.

In terms of the model, the system was divided into tunnels and stations, where geometric and physical variables are set.

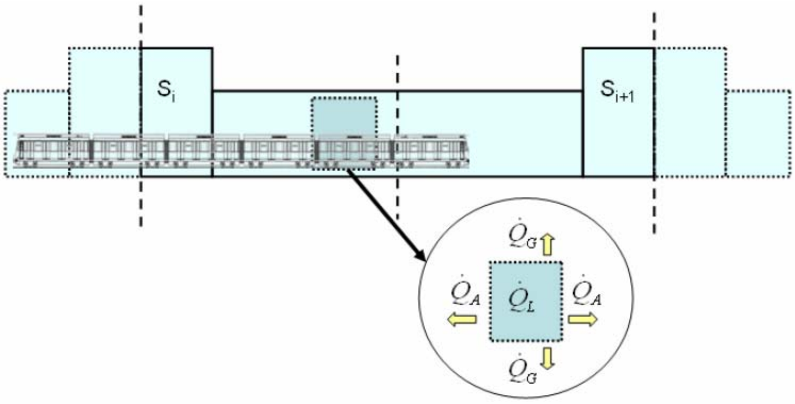



***Figure 22: Energy balance model through the line with a control volume***

For the developed model, heat loads of the train, air inside the tunnel, earth around the tunnel stations, passengers and other machinery, such as HEVACs, were interrelated by means of *heat transfer* equations. Different time-dependent equations were aggregated and discretised in order to establish the thermal equilibrium for each hour along a day.

Based on the developed model, the software called ModEnergy was developed in order to make the corresponding calculations. There are several screens where two examples of the interfaces are given in the following figures:

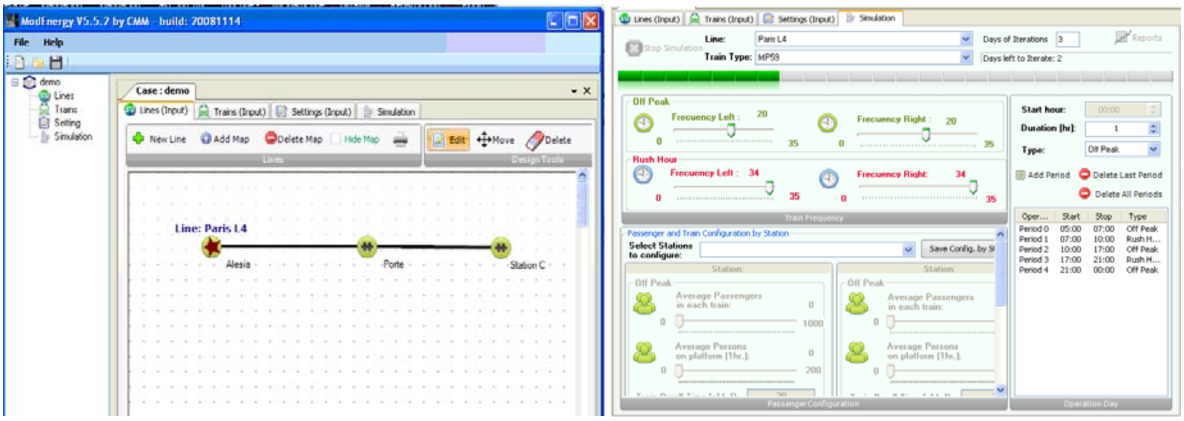



*Figure 23: Screenshots of the line editing and simulations interfaces of ModEnergy software*

The left-hand side figure corresponds to the input for the metro line, where different physical parameters and station distributions are defined. On the right-hand side figure, we observe the interface where the operational parameters of the train and the passengers are established.

Upon running the simulation, several output reports are generated. Considering the energy related to one train running along the line, two reports are shown:

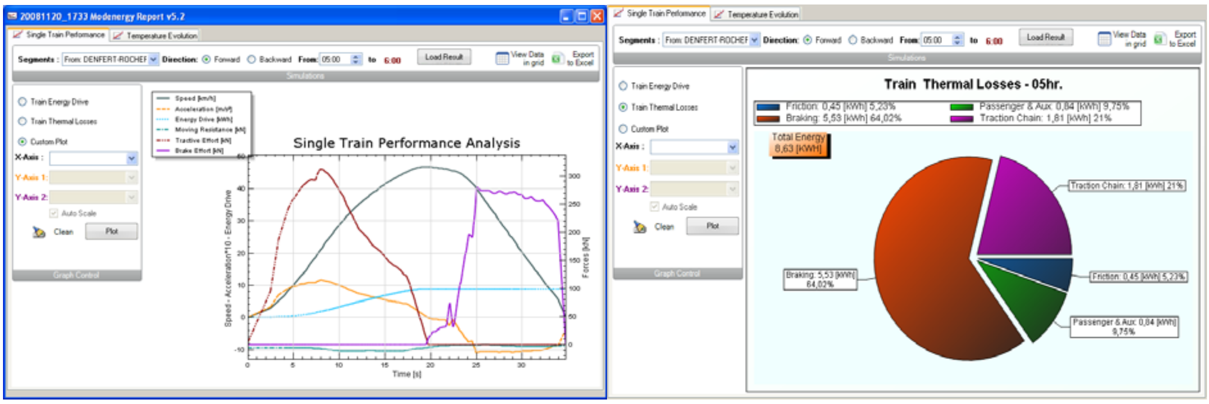



*Figure 24: Screenshots of the performance of a single train*

The first screen corresponds to the energy released and the different efforts of the train at different positions along the train-line. The second screen shows the overall energy breakdown of the trip from one station to the next one.

The other reports involve the display of the estimated temperatures:

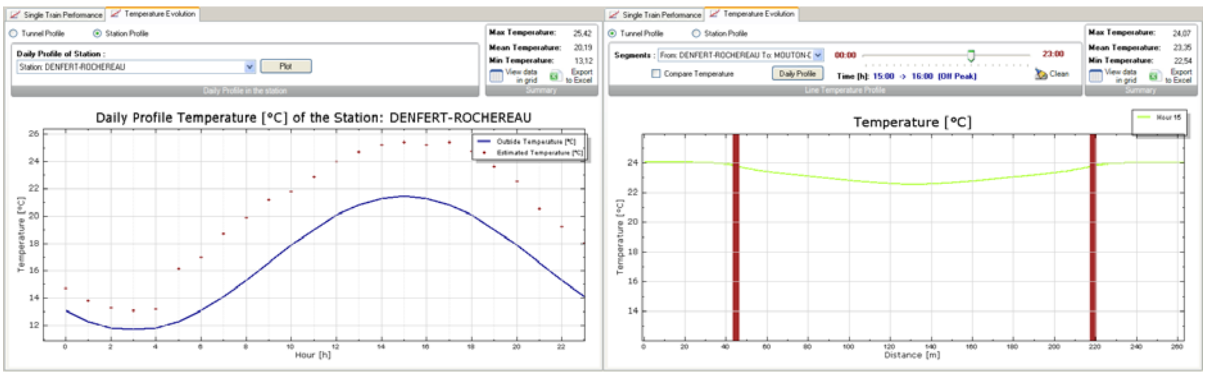



*Figure 25: Screenshots of the calculated temperatures along the system*

On the left hand-side screenshot, the average temperature inside the station along the day is depicted. The right hand-side one shows the average temperature during a certain hour of the day, along the different positions along the tunnel.

To test the performance of the model, some case studies were implemented: line 4 and China's Guangzhou Metro line 2. Upon these studies some recommendations were generated:

- RECOV is only recommended when wayside energy storage is available.
- The HVAC's set point temperature is important only at places where not extreme environment conditions are present. Under these conditions the set point temperature must be as high as possible in warm seasons and as low as possible during cold seasons. HVAC's Cop must be as high as possible.
- On cooling mode, currently there are not many technological solutions to be applied in order to have a clear energy factor advantage. Better efficiency and COPs values could be obtained with steeples control capacity systems, as frequency variation systems, but this will imply a big economical impact on the HVAC system, with no reduction effect on the other train systems.
- On heating mode, the application of Heat Pump technology will be an effective solution to reduce maximum and average power absorption values at HVAC system. Metro Tunnel environmental conditions are the optimal ones for Heat Pump operation, since no low ambient temperatures will be present and COP values from 2,5 to 4,0 could be obtained. At lower values, COP is similar to conventional electrical heating systems.

### 2.5.2. <u>WP 17: Energy savings by onboard storage</u>

The workpackage deals with the following objectives:

***Scope and objectives***

- Description and specification of applicable energy storage solutions
- Description of solutions (Energy Storage Systems; Energy Management Software)
- Quantification of the energy savings and the economic impacts
- Concepts for application in existing vehicles
- Validation of the concept

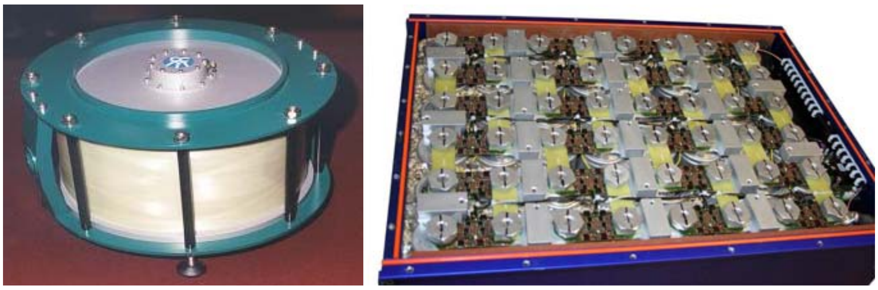


***Figure 26: Different types of storage systems (left: Flywheel of CCM, right: Ultracapmodul)***

***Achievements***

Possible onboard storage systems with basic principles are presented and compared to each other. The given data of different vehicle types, exemplary operational cycles and several control strategies for operational handling creates a base to decide which combination of technologies is considered to be the most efficient.

***Comparison of storage systems***

- Ultracaps:
  - Good system properties
  - The energy content is to low - 2011 Caps with 11 Wh/kg
- Flywheel:
  - high power density
  - product is available on the market
  - conformation to the rail application is necessary

- Batteries:
  - A very progressive development in the last years
  - Good system properties
  - Number of cycles too low

The two promising storage systems were taken as base to calculate theoretic storage behaviour in every day use for urban rail systems. In a first step, a tool to calculate the energy and costs savings by the use of storage system was created with the software Mathcad/matlab and needed input data were defined.

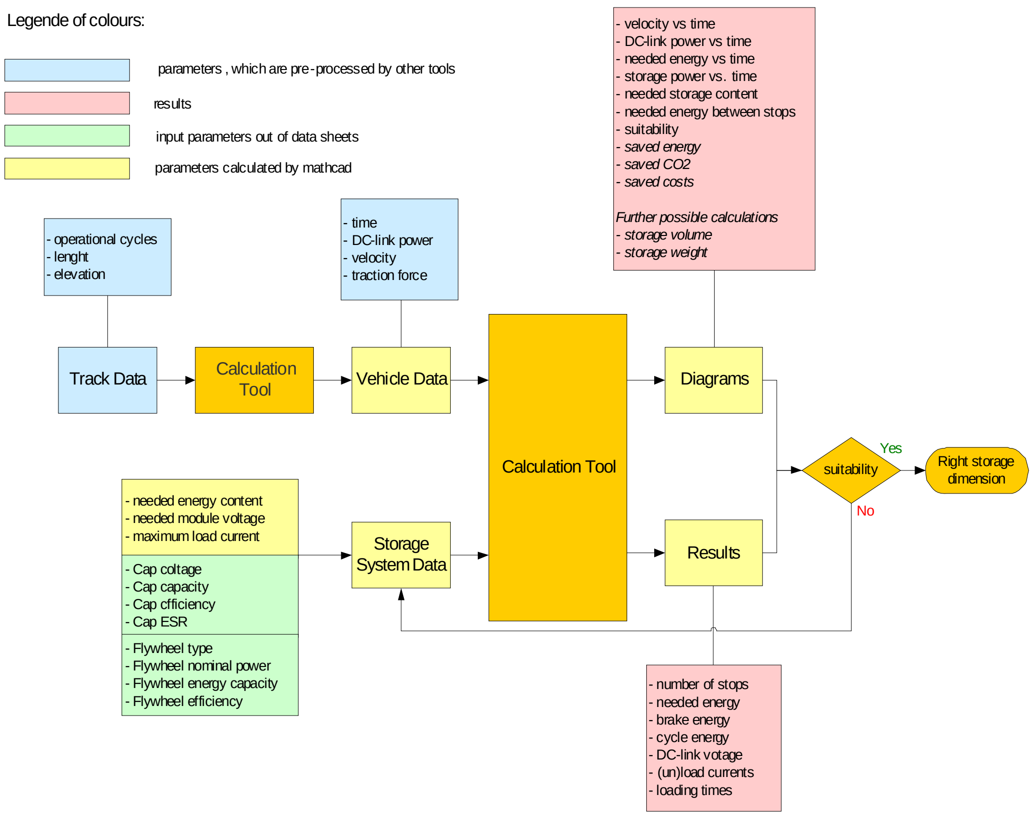



***Figure 27: Flow Chart of calculation software***

Based on these, the estimated economic and ecological effects were calculated. The quantification of the energy savings and the economic impacts were executed on the base of different tram and metro lines. Additionally, different concepts for application in existing vehicles were shown. Finally, a comparison between the efficiency of mobile and stationary systems for tram application was done.

***Figure 28: Different types of realised storage systems (left: Sitras MES of Siemens, right: Sitrac energy saver of Bombardier)***

***Conclusion and next steps***

- Calculation tools to analyse the energy savings by the use of energy storage systems:
    - Potential saving of 20 to 30 % in energy consumption
    - Additional voltage stabilisation in the power network
- Different case studies for three tram and three metro systems
    - In metro system the stationary systems are more useful
- Comparison of stationary and mobile storage system for tram
    - Mobile storage needs additional weight and place in the vehicle
    - But more flexibility through operation without overhead contact line
- The storage systems are ready to go to market
    - Examples Mitrac energy safer, Sitras HES / MES / SES, and Citadis Rotterdam
- Next steps: Standardisation of Ultracap-Modules

### 2.5.3. WP 18: Removing Constraints on the Use of Lightweight Materials

The workpackage deals with the following objectives:

***Scope and Objectives***

To provide engineers in metro vehicle production with the necessary information to allow them to specify lightweight materials in a systematic, robust and rational manner in order to provide affordable vehicles with reduced weight and energy consumption.

***Work Performed and Achievements***

- A state of the art review of typical current metro vehicles in terms of the materials used and their associated masses;
- The development of a material database for use in conjunction with the *CES Selector* material selection software. *CES Selector* assists engineers with material selection decisions in the early stages of a design process;
- Four metro vehicle case studies in lightweighting through material substitution:
    - Interior grab rail.
    - Gear-box casing.
    - External door leaf.
    - Interior floor panel.
- The prototyping of a lightweight interior grab rail and its installation on the Metro de Madrid MODURBAN tests train. The prototype was manufactured from a carbon fibre reinforced polymer composite and was 57% lighter than an equivalent stainless steel design;

- A quantification of the energy savings and economic benefits of metro vehicle lightweighting. A 10% reduction in vehicle mass was estimated to yield a 7% saving in energy consumption and a corresponding 100,000€ annual operational cost saving per vehicle;
- The preparation of two public dissemination documents – a paper for the *Journal of Rail and Rapid Transit* and an article for *Mobility* magazine.

*Figure 29: lightweight grab rail on the Metro de Madrid MODURBAN demonstrator train.*

### 2.5.4. WP 19: Power Saving through the Train Control System

Three main themes were defined:

- Traction power consumption and its relative importance
- The dynamics (rush hour, off peak)
- Algorithms for real-time power savings

Conclusions:

- Coordinated traction and braking can be an effective method of power saving
- Worthwhile including in new command/control systems
- But upgrade of existing systems may not be cost effective; this depends both on the state of existing vehicles, and the cost of electricity to the operator.

The technology is now being developed commercially for new trains.
Benefits for retrofitting existing rolling-stock should be studied further.

## 2.6. MODSYSTEM

### 2.6.1 Scope and objectives

The scope and objectives of the MODSYSTEM subproject were:

- To ensure functional and technical consensus building for MODURBAN, and coordination of the different subprojects,
- To define the Functional Requirements Specifications for the main critical elements of MODURBAN and their interrelations,
- To define the Technical Specifications including Architecture, Functional allocations, Performance, Interchangeable Modules and theirs interfaces,
- To define a system approach to Safety, taking into account human factor impacts and return of experience (accidents and anomalies databases),
- To define Conformity Assessment Procedures, on the basis of typical European cases,
- To put in place a on-site demonstration in Madrid through integration tests in a representative environment,
- To manage external networks involving operators and suppliers.

The MODSYSTEM subproject was organised around six workpackages:

- **WP20**: System Management/ Functional and technical consensus building
- **WP21**: Functional specifications (FRS)
- **WP22**: Technical specifications
- **WP23**: Safety and availability conformity assessment process
- **WP24**: On-site integration tests
- **WP25**: Management of external networks of operators and industry

### 2.6.2 Achievements

The achievements are the following:

#### *2.6.2.1 A global glossary for MODURBAN*

It gathers all terms and abbreviations used by all workpackages of MODURBAN.
It facilitates the common understanding of terms and abbreviations at a System level and allows avoiding inconsistencies between definitions and abbreviations used in different deliverables.

#### *2.6.2.2 MODURBAN Functional Requirement Specifications (FRS)*

The MODURBAN Functional Requirements Specifications (FRS) are fully endorsed by all operators and the entire consortium.
They contain the recommended functional and performance requirements, which constitutes the foundations of MODURBAN.
They are the result of many years of operating and manufacturing experience.

It is a complete set of "ready-to-use" requirements suitable for all operators and covering systems ranging from manually driven trains to fully driverless operation.
Inside the FRS, a common system core ensures seamless upgrade from one level of automation to the next, up to unattended train operation.

The FRS features are:

- Basic operational characteristics including Grades of Automation (GOA), interoperability needs, general requirements and degraded operations;
- A complete set of functions and requirements based on mandatory functions and optional functions according to the GOA covering functions for train operation (e.g. Ensure safe movement of trains) and functions for operation management and supervision (e.g. Manage mission);
- System performance criteria (e.g. Criteria related to passengers exchange).

The benefits are:

- The assurance of a comprehensive set of requirements which derives from years of experience of major players Requirements which truly represent "state of the art" in all these critical aspects;
- A simplified tender process through a win-win approach and a "performance" specification with no surprises:
  - Tenders in conformity with the MODURBAN FRS will avoid unreasonable or unforeseeable risk and cost factors
  - Reduced system costs for specific development and project implementation.

The MODURBAN FRS is an input for standardisation in progress on UGTMS (Part 2: Functional Requirements Specification) at international (IEC) and European (CENELEC) levels.

#### *2.6.2.3 MODURBAN Technical Specifications*

They contain a definition of a common architecture with an identification of interchangeable modules and an identification of the level of specification of interfaces (functional or full description).
An allocation of functions through a limited set of options is described.
They are applicable to all system configurations with or without existing interlocking, with or without secondary train detection, and implementing different levels of automation.

The other architecture features are:

- A fault tolerant Data Communication System transparent to the train control system where only one network supports all applications using international standard (IEEE 802.3) for interfaces and Internet Protocol (IP) for message routing
- Onboard and Wayside databases containing all details of the infrastructure lay out
- Integrated OCC with optional traction power supply control and supervision.

The benefits expected are:

- To simplify bidding;
- To reduce risk traditionally associated with the implementation of new technology;
- An anticipation of the requirements and development of standard off the shelf solutions to address the market;
- Different levels of automation allowing modular software and hardware.

This common architecture specification could become an input for standardisation in progress on UGTMS (future Part 3: System Requirements Specification) at international (IEC) and European (CENELEC) levels.

The basic MODURBAN system architecture is the following:

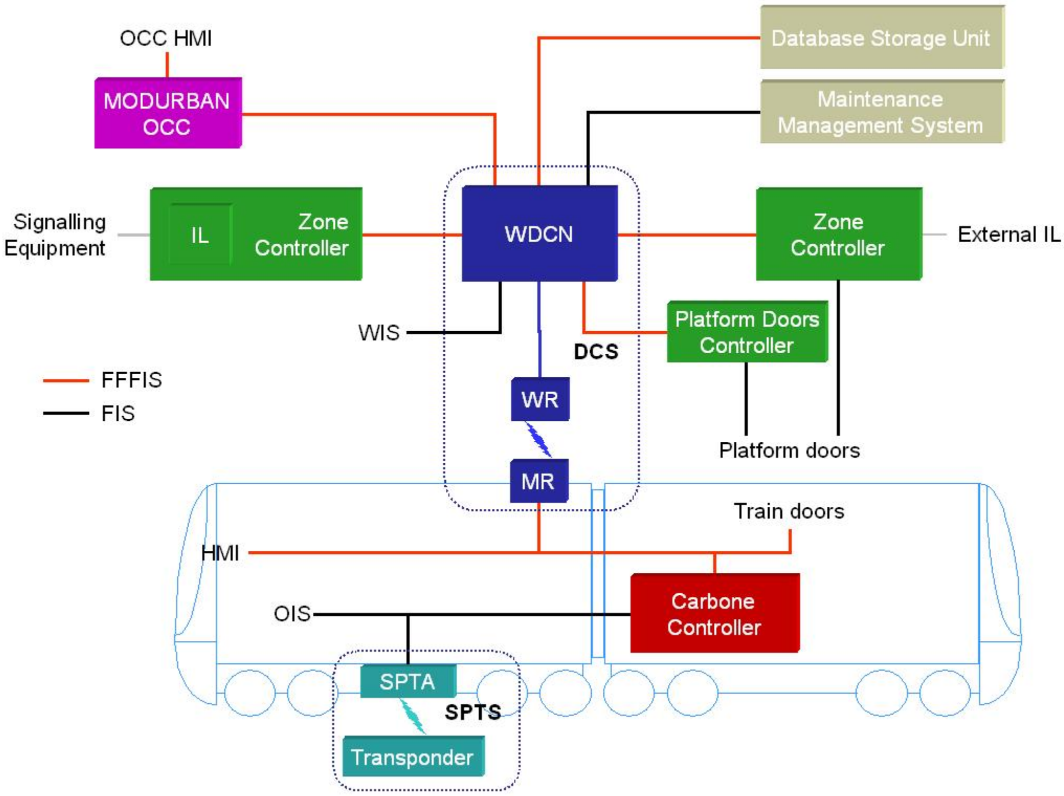



***Figure 30: MODURBAN system architecture***

### *2.6.2.4 System approach to safety*

The safety conceptual approach for MODURBAN focuses on risk assessment and Safety Integrity Level (SIL)-allocation for MODURBAN safety functions.

The features are:

- A generic model and guidelines for risk analysis
- Preliminary Hazard log: a generic Hazard Log for MODURBAN application
- Preliminary safety plan: a guideline for the establishment of a safety plan for MODURBAN during realisation projects
- An integrated human-machine assessment analysis method for functional and technical specifications of a system
- Method to evaluate human error probabilities
- Requirements and Specifications for data collection tool of non-conformity events and anomalies discovered during normal operations
- Description of a developed database system of non-conformity events
- State of the art on main guidelines, major key players and documents in the conformity assessment of urban guided transport
- A proposal for harmonised approval process.

The benefits are:

- Methods for Hazard and risk analysis
- Set of agreed safety requirement recommendations
- Sound basis for new research project supporting the cross-acceptance of urban transport system.

The results are inputs for the MODSAFE European research project and for the maintenance cycle in progress of European and International standards on safety (EN 50126-1, EN 50128, EN 50129, EN 50155).

##### 2.6.2.5 *Tests and demonstration*

The tests and the Final Conference in Madrid on December 16th, 2008 were a big success for MODURBAN with about 140 participants from Industry and Operators organisations.

An overview of the six subprojects results (MODONBOARD, MODWAYSIDE, MODCOMM, MODACCESS, MODENERGY AND MODSYSTEM) and of the specific integration tests to be demonstrated on the same night was presented.

This presentation was followed by tests until 4 o'clock in the morning in a real environment under real operating conditions showing the integration between different subsystems:

- Onboard intelligent automatic driving,
- Interchangeable Data Communication System (DCS) operations with three different DCS technologies,
- Passengers Information Systems and Video Surveillance Systems onboard and wayside,
- Lightweight materials for trains.


***Figure 30: MODURBAN final tests night***

##### 2.6.2.6 *Networks of operators and suppliers*

Networks of operators and suppliers were put in place promoting knowledge, stimulating debate.
An Europe-wide consensus on functional specifications has been achieved.

UITP Survey results (37 answers), on the problems of interoperability within one network and line extensions are the following:

- 80% of operators see an advantage in interoperability in their network
- 60% see an advantage to have independence between on-board and wayside equipment
- 40% are prepared to support higher initial cost due to interoperability
- 60% are interested to participate in a group applying the same common specifications for tenders.

## 3. Dissemination and use

The tables below show the lists of fully and partially public results. All these documents are available on the project's public website, www.modurban.org.

***Fully public MODURBAN deliverables***

These deliverables are available in their entirety to anyone for free use (Consortium members or not). They have become "UNIFE-UITP Technical Recommendations", jointly maintained by UNIFE/UITP.

| Item N° | Detailed Name | Subproject |
|---|---|---|
| D10 | Intelligent Automatic Driver Specification and Simulation Report | MODONBOARD |
| D11 | Intelligent Driving Prototyping | MODONBOARD |
| D12 | Integration and Validation Plan and Reports | MODONBOARD |
| D13 | Demonstration on Test Track | MODONBOARD |
| D14 | Transit version of the EUROBALISE specifications | MODONBOARD |
| D39 | Data Communication System Functional Requirements | MODCOMM |
| D40 | Data Communication System Performance, Reliability and Maintenance Requirements | MODCOMM |
| D41 | Data Communication System Architecture | MODCOMM |
| D46 | Requirements, list of relevant Standards for Onboard Passenger Information Systems | MODACCESS |
| D115 | Requirements, list of relevant Standards for Wayside Passenger Information Systems | MODACCESS |
| D47 | Functional Interface specification for Passenger Information Systems (onboard + wayside) | MODACCESS |
| D116 | Report on Optimised Application of Video and Audio Surveillance Systems | MODACCESS |
| D48 | Information for Passengers both in Driverless Trains and on Platforms | MODACCESS |
| D49 | Passenger Related Functions in Degraded Modes, Passenger Emergency Functions | MODACCESS |
| D50 | Final report on system critical passenger information and interaction, including results of Metro Madrid trials | MODACCESS |
| D51 | Guidelines/definition of Requirements for Door Systems on Innovative Driverless Urban Transport Systems | MODACCESS |
| D52 | Guidelines/definition of Requirements to Interface with Platform Screen Doors | MODACCESS |
| D53 | Functional and non functional interface requirements for platform door systems | MODACCESS |
| D54 | Installation requirements for platform door systems in new and existing stations | MODACCESS |
| D129 | Global Glossary | MODSYSTEM |
| D80 | Comprehensive Operational, Functional and Performance Requirements | MODSYSTEM |
| D86 | Safety Conceptual Approach for Functional and Technical Prescriptions | MODSYSTEM |
| D87 | Human factors and System Design – Integrated system for "Auditing" Safety Levels of Urban Guided Systems | MODSYSTEM |
| D128 | Risk Assessment based on Human Factors | MODSYSTEM |
| D126 | Preliminary Safety Plan | MODSYSTEM |
| D127 | Preliminary Hazard Log | MODSYSTEM |
| D90 | Generic Model / Guidelines for Risk Analysis | MODSYSTEM |
| D91 | Database of Non-Conformity Events | MODSYSTEM |
| D93 | Conformity Assessment, Guidelines for Functional and Technical Specifications | MODSYSTEM |

***Partially public MODURBAN deliverables***

In order to safeguard the Intellectual Property Rights (IPR) and other confidential information of some MODURBAN Consortium members, only selected parts of these deliverables are available to anyone for free use (Consortium members or not).

| Item N° | Detailed Name | Subproject |
|---|---|---|
| D25 | Data list for ATP and associated process definition | MODWAYSIDE |
| D28 | Benchmark Final report and tests results on selected formal tool | MODWAYSIDE |
| D26 | Tools Benchmarking Report including Formal Language Selection | MODWAYSIDE |
| D42 | MODURBAN Data Communication System Interface and User's Guide | MODCOMM |
| D59 | Final version of Energy Optimisation Software and Test | MODENERGY |
| D66 | Description and Specification of the three Design Concepts using Light Weight Materials | MODENERGY |
| D67 | Quantification of Energy Savings and Economic Benefits | MODENERGY |
| D121 | Examples of Mass Transit Operation scenarios and of Migration Paths | MODSYSTEM |
| D85 | MODURBAN Architecture, Identification of Key Interfaces and some Preliminary Functional Interface Specification (FIS) | MODSYSTEM |
| D88 | Requirements and Specification for Data Collection Tool of Non-Conformity Events | MODSYSTEM |
| D97 | Madrid Test Reports | MODSYSTEM |

**Coordinator's contact details**
Mr. Bernard von Wullerstorff (UNIFE)
Bernard.von.wullerstorff@unife.org
Tel: +32 2 626 12 63

www.modurban.org

PARTNERS: INDUSTRY PARTNERS RAILWAY OPERATORS R&D ORGANISATIONS OTHERS