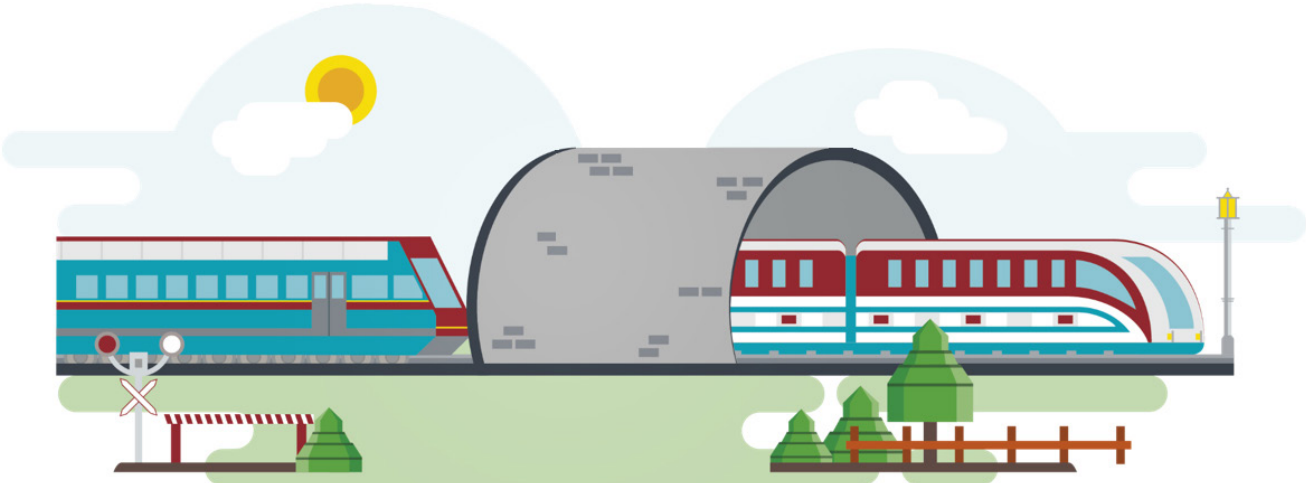
ASTRail

SAtellite-based Signalling and Automation SysTems on Railways along with Formal Method and Moving Block validation



FOREWORD

Newsletter June 2018

In the last years, several breakthrough technologies have become available and many of them have a huge potential for the renewal of transportations: as a result, some sectors, especially the automotive one, are rapidly evolving. In the case of railway transport, innovation needs to be introduced at a slower pace, because stricter safety requirements have to be fulfilled.

A promising way to accelerate the evolution of railways is to leverage the experience matured in other transportation domains: the outcome is not obvious because additional effort would still be required to adapt the existing solutions to the target context of railways and to carefully evaluate and validate the innovations in the specific application.

This is the rationale behind ASTRail project.

The ASTRail project aims to enhance signalling and automation system leveraging cutting-edge technologies from different sectors and taking in particular care the safety and performance issues. Enhancing the ERTMS with Moving Block System, Automatic Train Operations and GNSS positioning can ensure the competitiveness of the European railway industry, and, in the meanwhile, guarantee a concrete improvement in the quality of the European railway transport system, solving the problem of increasing demand on high density lines.

This project has received funding from the European Union`s Horizon 2020 research and innovation under grant agreement No: 777561

PROJECT STRUCTURE

The ASTRail project aims to improve technologies for signalling and automation investigating new applications and solutions that must be carefully analysed in terms of safety and performances. Insights from other fields, such as avionics or automotive, are necessary to exploit cutting edge technologies, scientific approaches and methodologies in the railway environment.

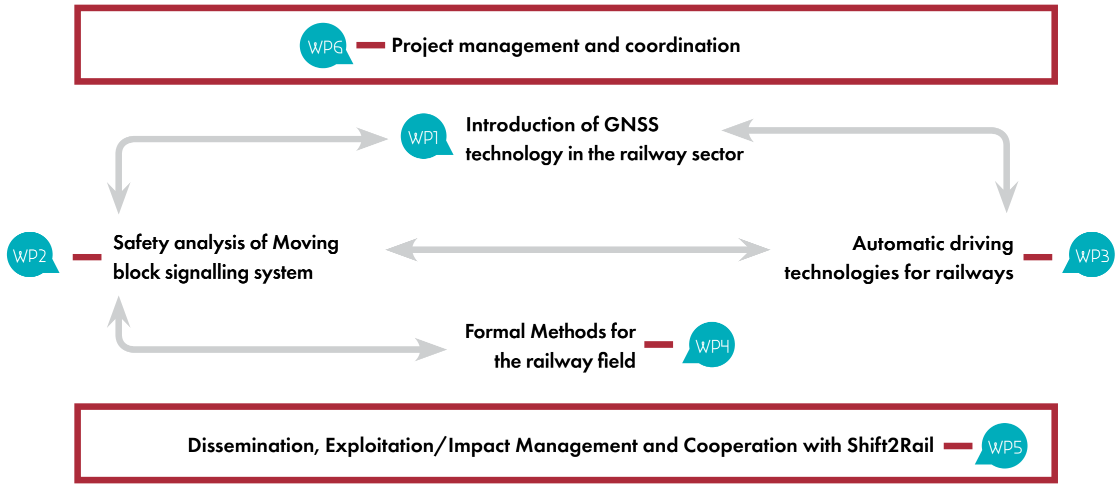


Figure 1. ASTRail project structure

The ASTRail rationale and aims are split into 4 main technical work streams (WSs):

- WS1: GNSS technology into the ERTMS Signalling System
- WS2: Hazard Analysis of the railway system (with a focus on “moving block signalling”)
- WS3: Automatic driving technologies for Automatic Train Operations
- WS4: Formal language and method to be applied in the railway field

The WS-es are only seemingly separate and, on the contrary, have strong interactions. In fact, the understanding of GNSS performance in railways will be crucial for its adoption, particularly in the new moving block signalling and for its integration within the solutions for the Automatic Train Operation; formal methods will be crucial to perform the hazard analysis of new signalling methods.

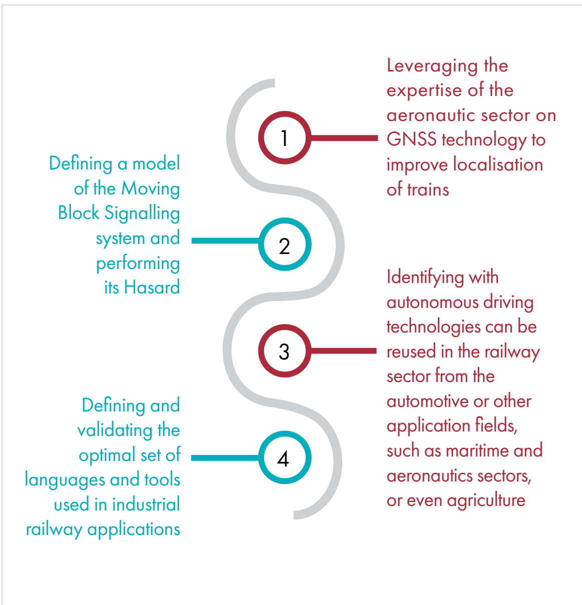


Figure 2. ASTRail technical objectives

ASTRAIL INTERACTION WITH SHIFT2RAIL

ASTRail is a RIA funded project under the call H2020-S2RJU-2017 and perfectly reflects the position of the Shift2Rail (S2R) Joint Undertaking, as stated in their Multi-Annual Action Plan (MAAP) roadmap -in particular in the Innovation Programme 2.t.

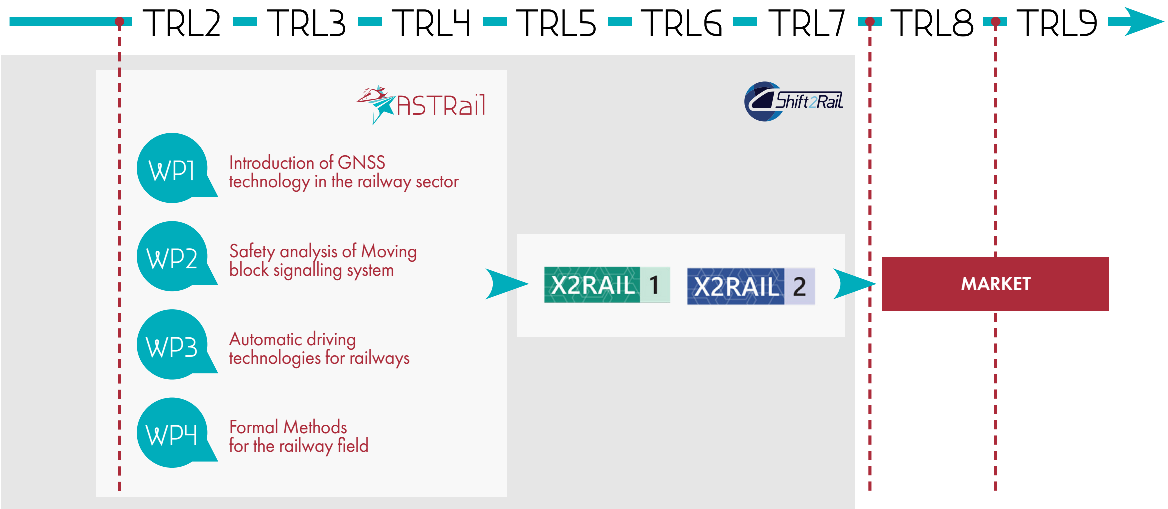


Figure 3. ASTRail project structure within S2R frame

ASTRail contributes to the achievement of the Master Plan and the MAAP objectives. Through the involvement of JU Members, ASTRAIL constitutes a good way of achieving the long-term technological demonstration programme within the Shift2Rail JU.

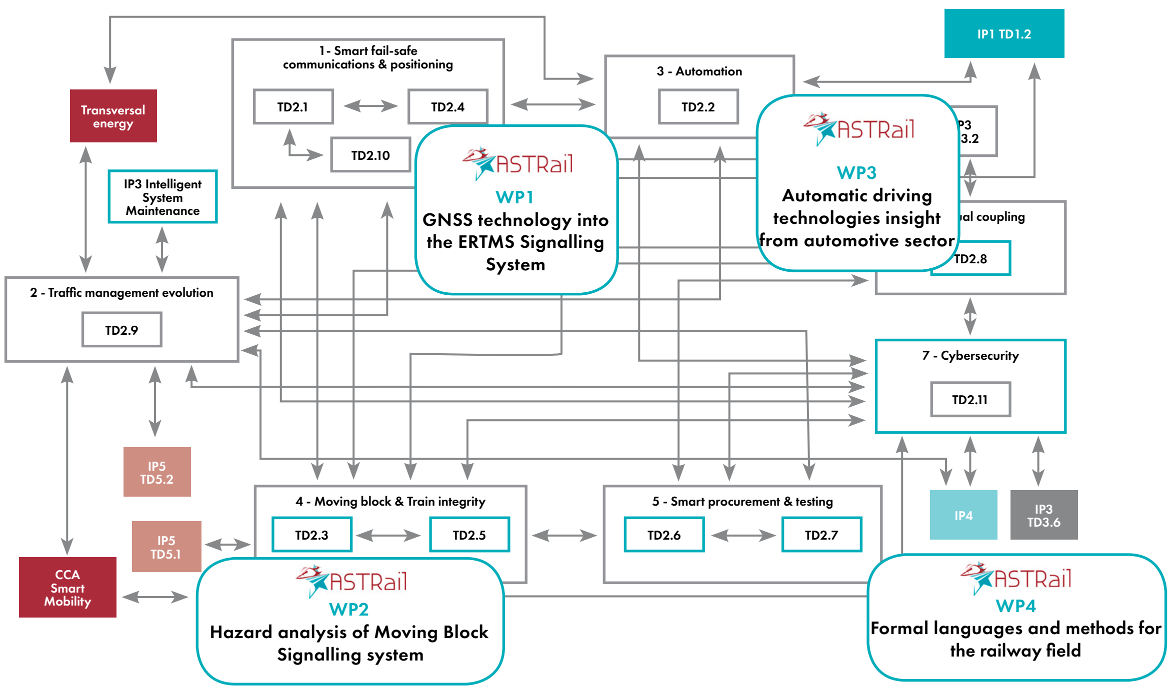
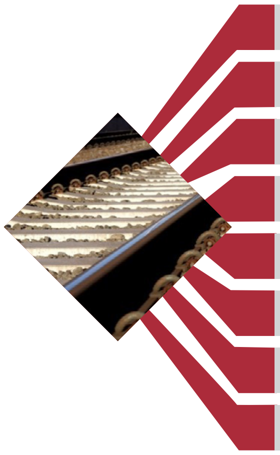


Figure 4. ASTRail is the moving towards achieving the main objectives of IP2

WP1 - INTRODUCING GNSS TECHNOLOGY IN THE RAILWAY SECTOR

ASTRail WP1 intends to analyse and transfer the applicable requirements and solution from the aviation domain to the railway sector, with a particular focus on the application of Fail-Safe train positioning to moving block signaling.
For this purpose, the WP moves its step from the review of aeronautical assumptions: the assumptions, requirements and metrics will be then transferred to the railways, identifying the elements which fit the GNSS-enabled rail applications.

The following steps will lead to the definition of a possible GNSS architecture cut for trains, considering technical aspects such as the suitable augmentation systems and the design rules for the target algorithms; the proposed solution will consider constraints such as hazard analysis of ERTMS related to GNSS faults and the error models known from the literature, eventually leading to the definition of a set of minimum performance requirements.



T1.1 **Aeronautical Assumptions Review**
identify the aviation standards pertinent to ASTRail

T1.2 **Aeronautical Requirements Transfer**
transfer relevant assumptions, metrics and requirements from civil aviation to rail

T1.3 **GNSS Local Error Modelling**
review of existing GNSS channel models and signal parameters classification

T1.4 **Augmentation System Integrity Assessment**
address various augmentation system options, including EGNOS

T1.5 **Hazard Analysis of ERTMS hazards associated with GNSS faults**
identify ERTMS hazards associated with GNSS faults and define mitigation strategies

T1.6 **GNSS Algorithm Analysis and Design**
selection and definition of a GNSS-centric architecture and GNSS algorithms design

T1.7 **GNSS Algorithm Performance Assessment and Verification**
select test plan for algorithms simulation and performance assessment

T1.8 **GNSS Minimum Performance Requirements for Rail**
propose hardware, software, equipment test procedures and operational requirements

Figure 5. WP1 tasks

Main achievements so far and next steps

An understanding of previous work in applying GNSS to the rail domain has been reached and expertise on the use of GNSS in the civil aviation domain, how the requirements have been derived has been shared to rail industry partners. Once this understanding was in place, a refinement of the philosophy for developing GNSS standards for rail has been made. Of particular note, the approach taken in ASTRail is to map railway RAMS requirements to the low level GNSS receiver requirements without the use of intermediate civil aviation style requirements.
Regarding local error modelling, the preferred models have been selected based on extensive literature review and have been refined using hardware and software simulations for suitability in the railway environment. The critical aspect is to have a model which is both realistic but not too complex so that simulations of high level performance may be undertaken in the later tasks.
On-going activities are focused on how civil aviation's augmentation systems might be best suited or reused in the rail industry. In particular hazard analysis of ERTMS faults associated to GNSS failure and how such faults are mitigated or transformed though the use of an augmentation system. The role of integrity monitoring algorithms is being assessed, in particular that of Advanced RAIM (ARAIM).

WP2 - SAFETY ANALYSIS OF MOVING BLOCK SIGNALLING SYSTEM

ASTRail WP2 performs hazard analysis of the Moving Block signalling system, in view of complete removal of trackside detection, with the aim to evaluate the viability of the system to comply with strict Safety Requirements applicable for all railway profiles including high-speed and high-density lines.

The model of the system will provide the basis for WP2 Hazard Analysis, considering use cases that will be defined by parameters such a system state (degraded operation, transition phases), traffic type, environmental condition (tunnels, urban areas, etc.) and Grade of Automation, and for WP4 validation applying selected formal methods.

T2.1 **Modelling of the moving block signalling system**
model the logical functionality of moving block signalling system without trackside detection

T2.2 **Definition of the system use cases**
main system use cases will be defined analysing significant system operative conditions

T2.3 **Hazard identification and risk analysis and evaluation**
safety assessment of a Moving Block signalling system will be initiated

T2.4 **Safety Related Application Conditions for operational procedures**
determine the operational procedure to be applied in normal or degraded conditions according to use cases defined in Task T2.2

Figure 6. WP2 tasks

Main achievements so far and next steps

To develop a level of understanding of the Moving Block system without trackside detection sufficient enough to enable its own safety analysis, the system architecture and a system model have been elaborated.

Since the ASTRail project's main interest lies in GNSS-based positioning systems for train detection, it represents a core component in the proposed functional architecture. Based on this, the system model has been developed applying semi-formal method UML state machine diagrams for the representation of the system.

This model will provide the base for the further development of the Hazard Analysis and will be used for the validation in the ASTRail WP4.

In parallel with system modelling, the System Use Cases have been defined analysing significant system operative conditions corresponding to the system states, modes of operation and operational conditions. The system states have been represented using the method of Message Sequence Charts.

After completing the system model, the Preliminary Hazard Analysis (PHA) procedure was initiated. The results of the analysis are recorded in the Hazard Log (Annex A of the deliverable D2.2) which contains the hazards identified during the PHA and the evaluated risk, proposed mitigations measures, derived requirements and SRACs.

From each hazard, a requirement has been defined which aims to reduce the initial risk to an acceptable level where possible. Where appropriate, a resulting mitigation measure and a formal property has been identified and recorded.

The residual risk corresponds to the level of risk after the application of identified safety requirements/mitigation measures; where the residual risk is different from "negligible", further mitigation (technical and/or operation) is needed. Due to the presence of the hazard with residual risk "tolerable", "undesirable" and even "intolerable", the further analysis will be conducted in the WP1 with the aim of providing the definitive conclusion regarding MBS system without trackside detection likelihood to comply with required safety levels.

The outputs of the Hazard Analysis will be also exploited in the T4.3 (WP4) for the formal validation of the moving block model. This validation will be based on the safety requirements mapped to formal properties suitable for validation process by formal method/s chased within WP4.

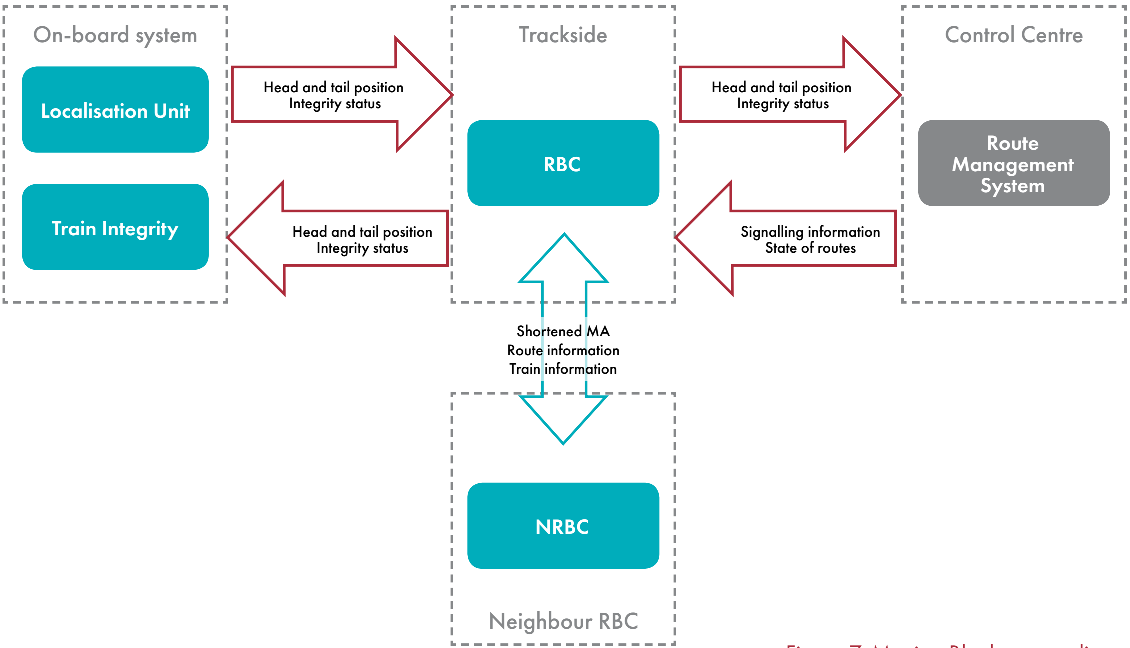


Figure 7. Moving Block system diagram

WP3 - AUTOMATIC DRIVING TECHNOLOGIES FOR RAILWAYS

ASTRail WP3 identifies the automatic driving technologies from the automotive sector and from other application fields (e.g. agriculture, avionics and maritime sectors) that seem more suited to improve Automatic Train Operation.

To achieve its goal, the following objectives have been identified and addressed by corresponding tasks:

- State-of-the-art technologies for autonomous driving, based on mature and cutting-edge solutions;
- Definition of the implementation characteristics and the types of applications that can be transferred in the railway field from the automotive and other sectors;
- Identification of the best autonomous driving solutions, considering specific use cases and different grade of automation in Automatic Train Operation (e.g. driverless or unattended operations).

Automated driving technologies in the automotive and in other application fields
identify which technologies are currently employed or under development in the automotive sector and in other application fields for automated driving

Analysis of Automatic Train Operations: operation conditions and implementation characteristics
determine implementation characteristics of automotive sector to be used in the railway and assess applications required during ATO for different degrees of automation

Assessment of automated driving technologies for railways
select most suited automatic driving technologies to be reused in the railway

Figure 8. WP3 tasks

Main achievements so far and next steps

Several technological solutions were considered, based on the initial state of the art technology and on heterogeneous transportation domains: landmarks, GNSS, wheel odometry, visual odometry, sensors, wireless solution, RADARs, LIDARs and many more.

The evaluation of such solutions in the railway sector needs to take into account several different features related to performances, requirements and operational aspects: they are not strictly related to one or the other and they may have a different relevance in the final evaluation, depending on the specific target scenario. For this reason, a parametric and flexible tool was needed and – in the plethora of Multi-Criteria Decision Making (MCDM) methods – the Weighted Sum Model (WSM) was adopted.

WSM works by setting some parameters for the evaluation and by assigning to each of them a weight. In the ASTRail analysis, the following variables were considered:

- **Maturity:** this was not considered critical since the ATO technology's readiness may evolve;
- **Accuracy:** considered highly important property, with a weight depending on each scenario that will be defined (e.g. precise positioning, precise detection);
- **Reliability** (qualitative, relative): highly important due to strict Railway requirements;
- **Availability** (qualitative, relative): highly important due to strict Railway requirements;
- **Maintainability** (qualitative, relative): highly important due to strict Railway requirements;
- **Cost** (qualitative): while the cost is important, the cheapest solution will probably not comply with all the criteria (specially, precision, reliability, availability);
- **Energy** consumption: the lowest consumption solution will probably not comply with all the criteria;
- **Suitability** to specific function requirement: a given technology could be a good solution for every use case but the more promising technology that best fit the need must be highlighted.

The evaluation was separately performed in the ASTRail target ATO scenarios, namely:

- Localisation of train for precise stopping in stations, yards or other special areas;
- Train localisation at the start-up;
- Localisation methods to calibrate the odometer;
- Detection of fixed obstacles on tracks;
- Detection of moving obstacles along the line;
- Detection of moving obstacles at stations, level crossing, yards or other special areas during shunting and other specific operations;
- Detection of cars and other vehicles at level crossing;
- Detection of safe location stopping area;
- Signals recognition.

Independently of the final marks, which deserve a more extensive assessment by the Stakeholders, the WSM permitted to come to some preliminary deductions which are here shortly recapped.

- Technologies for autonomous driving can be reused in railways, however a specific design of the sensors has to be performed to take into account the particular characteristics of the railway sector such as speed, braking distance, railway environment;
- The automated driving system of a train needs to satisfy different requirements for different ATO functions but also for the same ATO function, e.g., the obstacle detection function has to take into account that an obstacle can be a rock or a person, or that it can have a very large or small surface;
- Several technologies may be well suited to satisfy railway-specific requirements;
- At the same time, a single technology will hardly guarantee an effective and reliable solution for all operation conditions and needs: multi-sensors data fusion system seems to be the only viable perspective to properly satisfy autonomous driving requirements. Indeed, each sensor presents strengths and weaknesses and the multi-sensors data fusion system can take advantage on the specific strengths of a sensor to overcome weaknesses of other sensors.

WP4 – FORMAL METHODS FOR THE RAILWAY FIELD

ASTRail WP4 aims at identifying the most mature formal languages and methods to be used in the railway industry for safety-critical system and software development. This goal is achieved by means of a systematic literature review of formal methods applications in railways, and through trial applications of formal methods and tools for the ERTMS Level 3 Moving Block system concept and Automatic Train Operation principles. Surveys with practitioners are also performed to investigate the current uptake of formal methods and features desired by the railway industry.

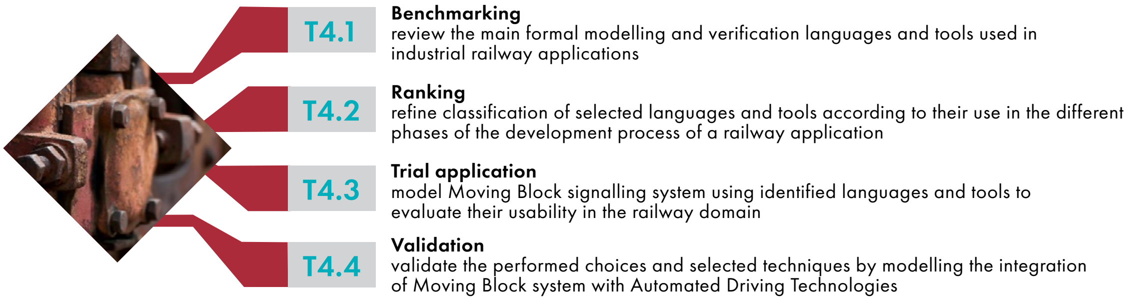


Figure 9. WP4 tasks

Main achievements so far and next steps

ASTRail WP4 has currently completed T4.1 and T4.2. The process followed together with the current achievements is represented in Figure 9. To address the goal of identifying the most mature formal / semi-formal languages and tools to be applied for the development of railway systems, a benchmarking task (Task T4.1) was performed, by gathering information from three different sources, namely Scientific Literature, information from other Projects, and Railway Practitioners.

Information from these sources was gathered through a Systematic Literature Review (SLR), a Projects Review and a Survey submitted to practitioners in the form of a questionnaire. The information was used to identify a set of main formal and semi-formal tools that appear to have been used in the railway domain (Relevant Tools). Specifically, scientific literature was used as a primary source, since it provides more extensive information for guidance in the selection of relevant formal methods, while other projects and railway practitioners were used as sources to complement the information from the literature review. Furthermore, information from railway practitioners was also used as a source to identify Evaluation Criteria for the different tools. These were applied to carefully evaluate the selected tools in a Tool Review, in which industrial partners were involved to assess the usability of the tools.

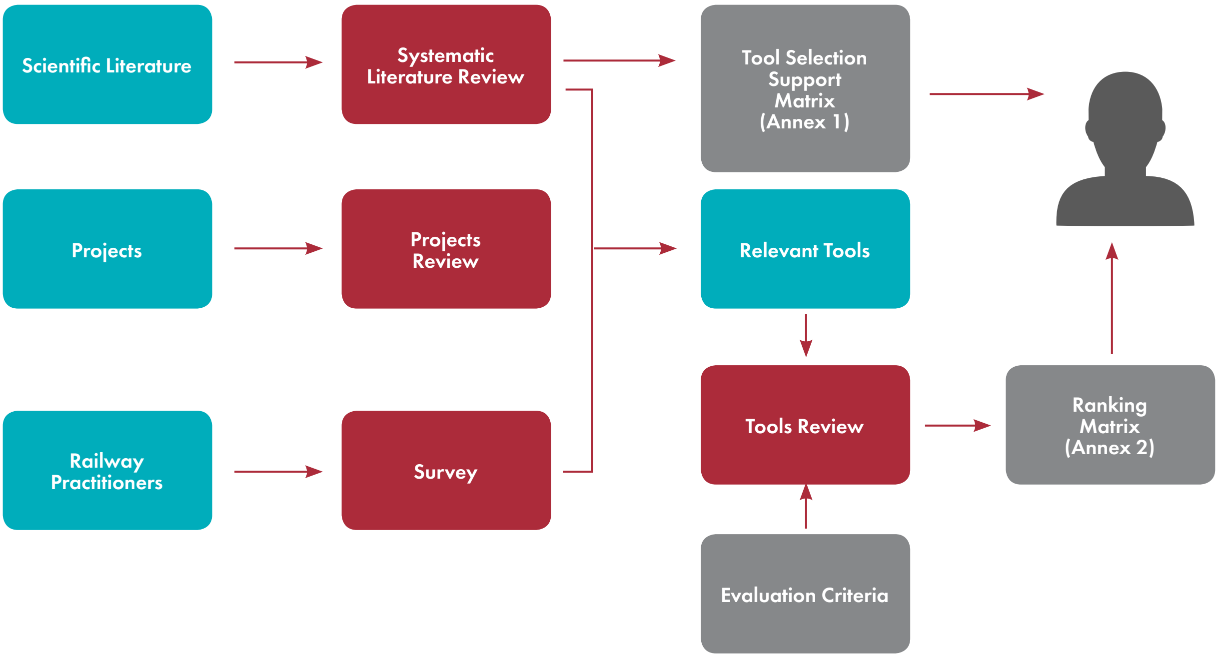


Figure 10. Overview of Current Achievements

The next steps within WP4 are the implementation of a high-level model of ERTMS Level 3 moving block to assess and formally verify its principles. The model will be implemented with at least three different tools that are considered appropriate for the task, according to the Tool Selection Support Matrix, and the Ranking Matrix. This will enable a more thorough comparison of the different formal methods and tools considered in the evaluation. Academic partners will perform this task. Then, during the Validation phase, industrial partners will integrate a model of Automatic Train Operation principles to assess the industry-readiness of the selected technologies.

PAST AND UPCOMING EVENTS

10/10/2017
Toulouse, France
Forum Méthodes Formelles 2017. The work done in the WP4 was presented.

15/11/2017
Pistoia, Italy
RSSRail International Conference 2017. During the conference the project was presented.

15/11/2017
Firenze, Italy
European Technical Working Group on Formal Methods in Railway Control.
During the working meeting the project was presented.

08/03/2018
Internal Seminar, ENAC
RAMS for GNSS. Educational dissemination action.

12/04/2018
Leiden, Nederland
Safety of Future Systems: Science meets Industry. The work done in WP4 was presented.

16-19/04/2018
Vienna, Austria
Transport Research Arena (TRA). During the conference the project was presented.

20/04/2018
Thessaloniki, Greece
3rd Workshop on Models for Formal Analysis of Real Systems (MARS 2018).
The work done in WP4 was presented.

18-21/09/2018
InnoTrans,Berlin Germany

A midterm meeting of the project will take place in the fall 2018.

FACTS AND FIGURES

1.8€ Million

6 Partners

24 Months

Project Start Date:
1st September 2017

Project End Date:
31st August 2019

Grant Agreement n:
777561

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