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Moving block and traffic management in railway applications: the EC project COMBINE

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Abstract

In the Fourth Framework Research and Development (R&D) Programme, the European Union (EU) has promoted, within Telematics Application Programme, several projects, devoted to Transport Sector, containing high profile telematics technology applied to planning and operational tasks. In this paper the authors present the main characteristics of one of these projects, called COMBINE, acronym of *enhanced COntrol center for a Moving Block sIgNalling systEm*. The project aims to lay the technical basis for the implementation of innovative optimisation tools in moving block traffic management systems; this requires both the analysis of moving block operation parameters and the definition of an effective system architecture for control system.

1 Introduction

The use of traffic regulation systems based on various algorithms for solving conflicts might provide its maximum effects when also the moving block signalling system is applied. For this reason the interaction of traffic regulation and the moving block should be investigated from an operational point of view in order to assess the expected benefits for increasing line capacity exploitation, reducing transit times of trains, reducing energy consumption during traction phases.

The use of traffic regulation and conflict solver systems in conjunction with the moving block implies several changes in traffic operation compared with conventional fixed block signalling systems. In situations where the "quite

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continuous" monitoring/command capability allows better use of infrastructures, traffic regulation must be very fine.
The objectives of the COMBINE project aim at improving the current research results in train movement and operation, taking into account problems and opportunities provided by the traffic regulation system when using the moving block instead of traditional signalling systems.
In particular, the regulation and the conflict resolution function will be implemented in a demonstrator where the moving block will be considered like a component of a closed-loop control system and the remaining parts of the "closed loop" (as lines, trains, drivers and functions of the traffic management system defined by the ERTMS – European Rail Traffic Management System) will be simulated.
The demonstrator will describe the traffic regulation functions and will emphasise and validate specific functions and requirements of the moving block. Functions and requirements to be validated are those enabling effective implementation of optimal resolution of traffic problems caused by instabilities in train speed profile, which occur in line sections preceding junctions or parts of lines with heterogeneous traffic.

2 Moving block in railway signalling

The fixed block concept employs fixed sections each made up of track circuits to detect the presence of trains. The track is divided into block sections with fixed boundary locations. The minimum length of these block sections are chosen to ensure protection under all operating conditions; the maximum lengths are determined by desired headway and operating speeds (Pascoe [1]).
The moving block concept can be defined as an automated control system allowing each train to receive (in safe mode) a "movement authority info" from the control centre. The control centre has to have a continuous dialogue with all the trains and to know continuously their speed and position. On this basis, the control centre can calculate and dispatch to each train (in safe mode) the current "movement authority info". Together with the "movement authority info" safe data, the control centre can also dispatch to the train some non-safe data, related to traffic regulation purposes.
The fixed block technology leads to lower dynamic performances with respect to the moving block. However, to obtain a full exploitation of the performances of the moving block, the control centre has to perform a continuous traffic regulation, suggesting the best drive parameters to the trains.
In railways no application has currently been implemented, but the basis for an integrated and interoperable system have been laid in Europe by the ERTMS Standard, now at level 3. Some metrorail and minimetro facilities have been equipped with moving block, but of course rated speed and operation environment are quite different from railway systems. The above description highlights the assets of moving block versus the traditional fixed block: "virtual" block section may "stretch" according to traffic and traffic control can be acted regulating speed instead of stopping trains at fixed points (wayside signals).

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From the above consideration it clearly appears that moving block allows smooth control of traffic and, reducing stop-and-go of trains, makes possible a lower energy consumption. Furthermore, smooth control of traffic improves exploitation of lines capacity, with relevant benefits for railway competitiveness among transport modes.

3 Traffic management in moving block

Automated traffic management can improve fixed block operation, as the results of the MARCO project (EU DG XIII IV Framework Program) testify. In this project automation of dispatching has been studied with field tests in railway and metro systems (De Vilder [2], Savio [3]). Among the other benefits, a significant increase in added value connected to human dispatchers work may be obtained. An experienced dispatcher may delegate repeating or trivial conflict resolution to the automated system focusing attention on overall control of traffic in the assigned area or guiding automated solution with the experience or the knowledge of elements which might not be considered by the automated system (availability of alternative rolling stock, alternative locations for crew shift change, etc.).
If fixed block operation may be improved by use of an automated control system, in moving block traffic control automation appears to be a key point for successful operation of this signalling system. As previously said, in moving block “fixed points” are only related to physical discontinuity of the line, thus trains may be, whenever possible, conveniently slowed down while in fixed block should have been stopped. But slowing trains to allow, as an example, crossing requires a very fast calculation of speed of at least two trains to assure adequate clearance between them; furthermore slowing a train may require to change speed of one or more trains following it. This task is not trivial, although possible, even to trained human dispatcher, while may be performed in a quick and error free way by an automated system.
Controlling traffic by keeping a continuous flow enhances the aforementioned benefits of moving block; the need for an automated traffic control system thus clearly appears.
Utilising the information derived from the configuration of the ERTMS, COMBINE project concerns the “new” or “renewed” traffic regulation functions (not-safety related) of a centralised Traffic Management System (TMS) for railway systems equipped with moving block.

4 The COMBINE project

The COMBINE project is funded by EU DG XIII (Telematics) in IV Framework Program; the duration is 24 months from January 1999.
COMBINE will determine the operational and technical parameters of the traffic regulation system in conjunction with the moving block for building a control system, that is capable of efficiently implementing the optimum traffic control solutions. COMBINE will also test the relevance of the most important technical

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parameters in defining the optimum achievable local control area and the interfaces and relations to the other levels of a generic architecture of a train traffic control system.

The aim of the demonstrator is to study the specific functions and requirements of the TMS when using the moving block. A large set of tests will be carried out in order to analyse the relevance of different technical parameters (speed profile update rate, communication technology delays), giving as a result performance requirements for industrial applications.

Another set of tests will be performed to verify the advantage of using a TMS in terms of punctuality increase, energy consumption decrease, infrastructure throughput capacity increase and capability of solving local conflicts when using a moving block signalling system.

As far as the COMBINE consortium is concerned, the project gathers users, suppliers of railway control systems and research bodies.

Users are represented by *Railned* and *Holland Railconsult*; the first is established to optimise the use of Dutch rail infrastructure and to monitor rail safety in the Netherlands, the second is market leader in the Netherlands in the field of engineering consulting firms for public transport and railway infrastructure.

System suppliers are represented by *DaimlerChrysler Rail Systems*, *CO.S.MO.S.* and *On AIR*. In the project are involved the Italian and Finnish companies of *DaimlerChrysler*. The Signalling Division of the Italian company, co-ordinator of the project, is one of the leading suppliers of rail traffic management systems in Italy; it has developed and commissioned in many Italian railway areas CTC (Centralised Traffic Control) systems and systems with Train Describer, Train Graph and Conflict Resolution functions as part of a more complex supervisory system, both for the Italian Railways and Metros. The Finnish company main activities are producing of integrated traffic management, power & infrastructure SCADA and passenger information systems. *CO.S.MO.S.*, located in Genova, is active in simulation consulting and development of complex simulation applications. *On AIR* is a Genova-based SME, whose main goal is to design and develop high-tech solutions for industrial applications: the company carries out R&D activities, realises prototypes and provides services based on advanced information technologies.

Research institutions involved in the project are the *Department of Electrical Engineering* of the University of Genova and the *Department of Computer Science and Automation* of the "Roma Tre" University.

The project is organised in seven Work Packages (WPs); the general contents and the responsible partner for each WP are reported in Table 1.

To date, a physical railway system operating with moving block is not available. Then, validation will be developed in a simulated environment using data coming from best expert guess.

On the basis of both the user requirements and functional analysis results, which will define:

- general operation requirements and performance parameters of moving block system;
- "new" or "renewed" functions related to the conflict management,

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the aforementioned demonstrator will be specified and developed, performing a relevant subset of the functions required to an industrial product and taking into account the state of the art for the moving block signalling systems.

Table 1 – Work Packages, tasks and responsibles

WP Description	Tasks	Responsible
1) Project Management	General management, organisation activities, administrative and financial management.	DaimlerChrysler Rail Systems (Italia)
2) External Liaison	Management of the interaction with user groups, production of information materials, WEB pages.	University of Genova
3) User Needs	Status of the art report, user identification, functional analysis of user needs and constraints, system performance requirements.	Railned
4) System Architecture	System context definition, system architecture development, algorithms choice, COMBINE logic model.	DaimlerChrysler Rail Systems (Italia)
5) Demonstrator	Demonstrator specification, traffic regulation modelling, development and integration of demonstrator.	DaimlerChrysler Rail Systems (Italia)
6) Verification	Case study, data collection, definition of significant traffic scenarios and test procedures, verification of demonstrator, quantitative analysis of operational and regulation parameters.	Holland Railconsult
7) Evaluation	Evaluation planning, quality assurance, evaluation reporting.	University of Genova

The site chosen for the verification is the Breda junction (see Figure 1) in the Dutch part of the high-speed line Paris-Brussels-Amsterdam.

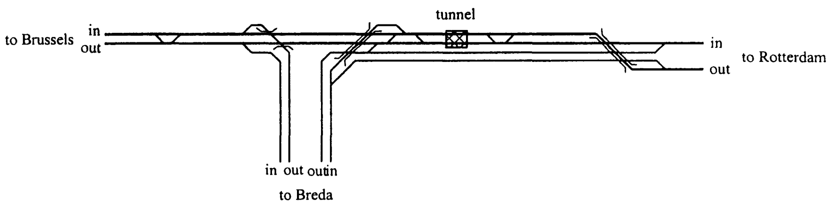

Figure 1– The Breda junction

This site has been chosen for the COMBINE project since it will constitute a real world site in the near future (2005). As yet, the site is still in the design stage and construction will not be completed during the COMBINE project.
The expected traffic on the junction includes both high speed and shuttle trains. TGV's run on the main line from Amsterdam to Brussels. Shuttle trains run from Rotterdam to Breda and from Brussels to Breda, where merging and exiting is

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done via fly-overs. As far as traffic composition is concerned, the objective is the smooth merging of the shuttle trains from Breda into the main line TGV traffic.

5 System architecture

A scheme of the COMBINE architecture is reported in Figure 2. Two main sections can be identified: TMS and Field Simulator. The TMS contains control function and optimisation tools to be developed in the project; it is responsible for controlling the trains by means of advisory speed profile (or target speed, position and time) and booking the train routes. As previously said, the unavailability of a working railway system equipped with moving block requires to simulate field; the Field Simulator simulates the real environment and the ERTMS level 3 safety system.

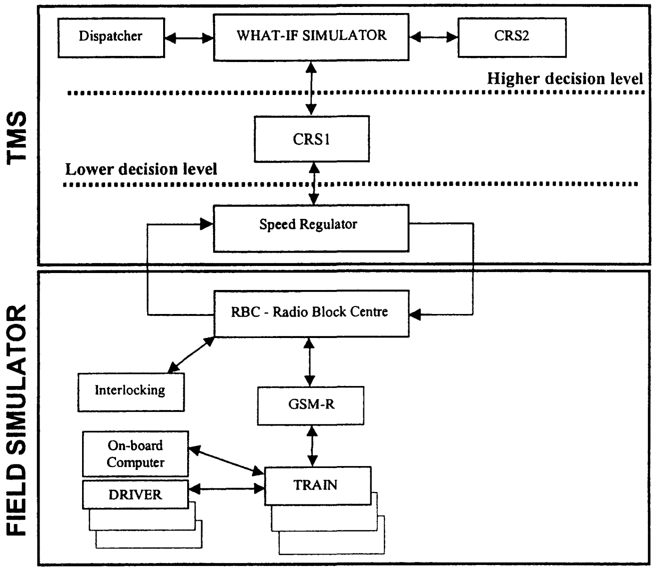

Figure 2 – COMBINE system architecture

As far as the TMS is concerned, the *Speed Regulator* controls trains by means of the speed and optimises it with reference to targets like punctuality or energy consumption. The lower level *Conflict Resolution System CRS1* controls a limited area verifying the fulfilment of targets.
At the higher decision level, a second *Conflict Resolution System CRS2*, controlling a wider area (and possibly more than one *CRS1*), automatically generates a new off-line plan when the targets are not fulfilled by plans generated by one of the controlled *CRS1*, which is shown to the *Dispatcher*. The *Dispatcher* evaluates the new plan and decides whether to change it or to send it to the *Speed Regulator*. The *What-If Simulator* allows the *Dispatcher* to test different alternatives. Once a solution has been accepted by the *Dispatcher*, the

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CRS2 sends it to the *CRS1* and the proposed plan becomes the (new) current one.
The Field Simulator is responsible for simulating:

- the *driver* behaviour (two types of drivers will be considered: a non-autonomous driver with an associated response time to the advisory speed profile or target, an autonomous driver that drives without the TMS control);
- the *on-board Computer* algorithm (it decides how to reach the target position, time and speed given by the TMS);
- the *train* performances;
- the *GSM-R* communication time (a parameter that permits to consider a delay due to the time needed to send and receive messages from the trains);
- the *RBC* and *Interlocking* systems (responsible for movement authority and routings).

The TMS will provide the Field Simulator with an advisory speed profile (or target) for each train and booking of routes.
The data flow from Field Simulator to TMS consists in train position, speed, acceleration, movement authority info, route status info (setting/release of route performed), infra availability.

6 Verification and Evaluation

According to EU definitions, Verification concentrates on testing the physical functioning of the application and acceptance of the application by a restricted group of users. Evaluation is aimed to impact analysis and acceptance of general users, and has to define the added value of the application (D'Addio [4]). The aim of one set of tests will be to verify whether the demonstrator indeed satisfies the requirements. That is, system level integration tests and verification tests are designed, as depicted in the following Figure 3, in a "V" scheme.

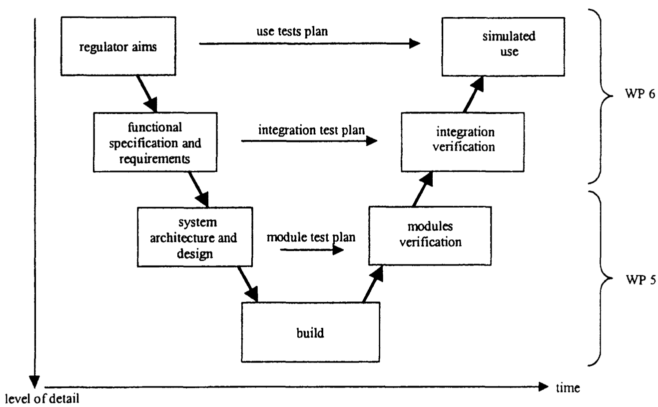

Figure 3 – COMBINE tests scheme

Only the functioning of the demonstrator as a whole will be addressed, as depicted in the following Figure 4, assuming as input a working demonstrator.

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This means that as a starting point it is assumed that the tests of the technical modules, including low-level integration test, are done by their developers and successfully passed. In particular, the Field Simulator should have been tested with respect to its agreement with the real-world train behaviour and safety system behaviour, while the TMS should have been tested for its ability to provide sensible optimisations.

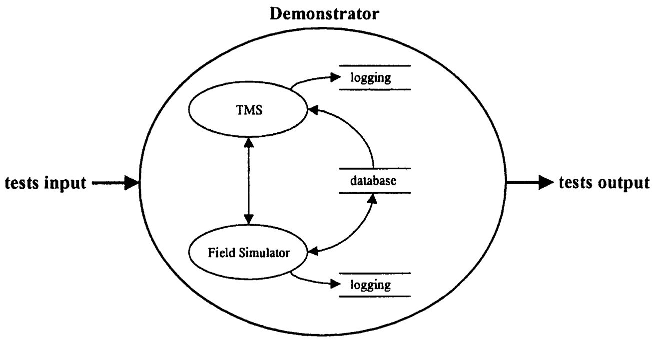

Figure 4 – COMBINE demonstrator test scheme

Another set of tests will be performed by the Verification team in order to assess the influence of technical parameters on the operation of moving block. To this aim, the following parameters have been identified:

1) Delay times in the management loop:
    - train position and speed sample time;
    - *GSM-R* communication time delay from train to TMS;
    - computation time of speed optimiser, of conflict detection (by speed optimiser) and of conflict resolution (by higher level);
    - update rate of advisory speed profile or targets;
    - *GSM-R* communication time delay from TMS to train;
    - reaction time train driver;
    - train dynamics.
2) Accuracy of train speed, position, acceleration measurements (together with sample time and *GSM-R* delay, i.e. maximum age from timestamp, and maximum acceleration or deceleration, this gives the data accuracy).
3) Accuracy of following the advisory speed profile (reaction time driver and execution accuracy of advisory speed commands).
4) Preview time.
5) Extension of the local control domain.
6) Look-ahead or *What-if Simulator* estimation accuracy (note that a larger preview time will reduce the estimation accuracy).
7) Criterion and weighting functions in the criterion.
8) Delay and energy consumption threshold for higher decision level call. Three events may be identified:
    - when speed optimiser solution above threshold one → ask higher level for solution;

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- when higher level solution above threshold two → warn dispatcher;
- when higher level solution above threshold three or global changes in plan → ask for clearance from dispatcher.

The following preliminary considerations should be made by the Verification team when planning parameters impact tests in order to assure significance and usefulness of results.

Accurate analysis of technical significance of parameters allows to find parameters which may be suitably batched reducing the set of issues to test, but, most important, improves the soundness of parameters impact assessment assuring that results have clear physical significance. Furthermore consideration of technical aspects may lead to reduction of situations to be tested or to focus attention on most likely scenarios.

The technical relevance of parameters is also a good criterion to state the required precision in evaluating parameters variation intervals and measuring their variation effects. Some parameters will represent physical constraints which are not assumed to be influenced by evolution in technology, while other ones may be significantly affected by different technical choices. The need for precision is quite different for the two categories above; as a matter of fact, the effort in estimation of a parameter which is subject to significant changes according to the evolution of technology used may be assessed taking into account economical consideration (i.e. possible economy arising from changes in technology, ratio between cost connected to a part in the system influencing a parameter and impact of the parameter affected).

At last, it should be noted that assessing the influence of parameters on moving block operation gives valuable information as far as external impact and exploitation of results are concerned. Knowledge of aforementioned parameters and their effects allows to focus the research areas related to the improvement of technology used in moving block signalling systems and represents a relevant project added value element, more than the cold numerical estimation of one of its outputs.

Once performed the two sets of tests, the Verification work package will be finally able to assess the impact and values of parameters on moving block operation, and the system performance in terms of fulfilment of users requirements.

Starting from the results of the Verification phase, Evaluation will then focus attention on the link between values of parameters and the user acceptance and, as far as system performance is concerned, on the appraisal of benefits that may arise from implementation of COMBINE tools in a moving block.

7 Conclusions

The purpose of the COMBINE project is to investigate the traffic conflicts, their effects (punctuality, backwards propagation, etc.) and the relevant automatic resolution procedures in moving block equipped railway systems, taking into account technological constraints and energy consumption problem too.

As discussed in this paper, the fundamental issues, from both a technical and an

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operational point of view, of building an innovative TMS for moving block signalling systems will be addressed by the project.

A demonstrator will describe, in a simulated environment, the traffic regulation functions and will emphasise and validate the specific functions and requirements of the moving block that enable effective implementation of optimal resolution of traffic problems caused by instabilities in train speed profile occurring in line sections preceding junctions or parts of lines with heterogeneous traffic.

In this context, particular attention will be devoted to the analysis of the technical parameters influencing control action effectiveness, as the knowledge of their impact on moving block operation will provide valuable information about the future areas of research and improvement of signalling systems technology.

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