1. Introduction

This paper reports on the results of a project funded by the European Commission under the Telematics Application Programme (TAP, 4th Framework Programme for RTD), called “enhanced Control centre for a Moving Block signalling system”, hereinafter referred with the acronym “COMBINE”.

The COMBINE Project analyses opportunities and problems provided by the Traffic Management System (TMS) when using the moving block signalling system for railway operation. The site chosen for verification is the Breda triangle in the Dutch part of the high-speed line Paris-Brussels-Amsterdam. Currently, there are no applications of moving block on main-line railways, apart from several test installations.
The introduction of ERTMS concepts will bring a strong interest in high performance train control systems capable of optimising traffic characteristics through the use of moving block.

Rail traffic regulation problems can be classified into categories according to the planning horizon considered. In this paper we deal with the daily tasks that are performed by taking into account the fine details belonging to the operational level. In particular, we will focus on the real-time control of the trains.

High speed computers and recent technological developments, such as automated train protection (ATP) and advanced train control systems (ATCS), have provided railroad with real time information on the position and speed of the trains, which allow to automate many real time functions in rail operations such as controlling and rescheduling train services. Many rail companies are now developing and implementing ATC systems, as reflected in many railway professional journals. This systems should help in reducing energy consumption and increasing train punctuality and line capacity.

Due to the complexity of the rail operations, railroad commonly operates with a master schedule strategy. With this strategy, a feasible tactical schedule is produced in advance for each scheduled train. All these schedules must be logically consistent in the sense that they are part of an operating plan that can achieve the times stated in the schedule with high probability, given the delays encountered by each train as a result of random occurrences (weather conditions, minor breakdowns, and so on) and interference with other trains. For freight trains and other trains that do not work on a schedule basis, a set of empty scheduled slots is reserved. That is, trains would not be permitted to depart at random but rather should depart within a stated time window if they are to be operated on a given day.

Clearly, when detailed tactical schedules are developed for all trains, unforeseen events such as the temporary unavailability of resources (e.g. drivers, wagons, engines, signals, energy power, etc.) may require to partially modify in real time the plan of operations on which the tactical schedules are based. This on-line process is called \textit{train dispatching} or \textit{conflict resolution}.

Even if the conflict resolution is presently performed by human dispatchers all over the world, several computerised systems has been designed and implemented to support the dispatchers to quickly and effectively re-schedule the train movements.

2. Approach

Preliminary activities of the COMBINE project aimed at defining a set of user requirements and a general architecture for a TMS operating within the ERTMS level 3 environment. Then, a demonstrator has been developed in order to test the goodness of the proposed architecture and the effectiveness of its optimisation algorithms. The demonstrator has been structured considering the moving block signalling system as a component of a closed-loop control system. Various elements of the real world environment (such as lines, trains, drivers, RBCs, GSM-R and relevant functions of the traffic management system defined by the ERTMS level 3) have been simulated.
The Demonstrator’s Architecture is composed of two main components: (1) a Traffic Management System (TMS), devoted to control train movements, and to detect and resolve conflicts in a moving block environment, and (2) a Field Simulator (called SimRail), simulating the communication between the TMS and the RBC, the interlocking systems, the infrastructure and the trains running in the test site area, according to given schedules and targets. In turn the TMS is divided into a hierarchy of three components:

- Conflict Resolution System level 2 (CRS2): it controls the whole area helping a Dispatcher monitoring it and taking decisions. The Dispatcher is also helped by a what-if simulator.
- Conflict Resolution System level 1 (CRS1): it detects and solves conflicts arising locally within a given area.
- Speed Regulator (SR): it controls the train movements in a moving block environment, by means of either advisory speeds or targets.

The Conflict resolution system is based on the alternative graph representation of the train movements, developed by Mascis and Pacciarelli (2000). The alternative graph is a powerful discrete optimisation tool, especially designed to deal with scheduling problems. It is able to include in the optimisation model a number of relevant features that are frequently neglected in most of the models from the literature on train scheduling. At the same time it allows to obtain effective solutions in a fast way. The speed regulator algorithm as been implemented as a fast algorithm, able to control the train speed. It performs basically a sequence of four phases: update scenario, speed evaluation, route booking, send advisory speeds.

An extensive simulation study was carried out in order to evaluate the TMS performance. A first set of tests has been performed in order to address the correctness of the TMS demonstrator developed during the project. A second set of tests permitted to analyse the impact of technological parameters (e.g. GSM-R communication delays) on TMS performances within a moving block environment.
3. Results and Achievements

Within the COMBINE project an interesting theoretical and practical analysis was performed about the effect of the technological parameters on the performances of the traffic regulation system. It turned out that a Traffic Management System can cope even with large GSM-R communication delays and considerable approximation errors on train position and speed, yet with only minor degradation of the overall system performance. Simulation tools and algorithms developed during the project demonstrated the validity of the proposed architecture.

![Control loop delay and analysis](image)

**Figure 3: Control loop delay and analysis**

A huge number of functional tests verified the demonstrator ability to optimise the traffic in a wide set of different cases. Another interesting set of tests aimed at showing whether advanced optimisation algorithms are useful to manage railway traffic. Such tests demonstrated that the optimisation algorithms applied in the COMBINE project turn out into valuable advantages in terms of better punctuality and energy saving when compared with other common dispatching rules.
Figure 4: Test results (1)

Figure 5: Test results (2)
4. Conclusions and Plans for the Future

The COMBINE project resulted in increased knowledge on railway operation in the ERTMS/ETCS level 3 environment. Although born as a pure research project, COMBINE provided technical specifications and software tools very close to the quality standards of industrial level products. Further steps of this research will be:
- To include new modules in the Demonstrator, in order to be able to simulate different signalling systems: fixed block and all ERTMS levels (COMBINE deals with ERTMS level 3 only).
- To create a network of \( n \) TMSs able to control a large railway network divided in \( n \) local control areas.
- To use these simulation tools for suggesting standards and solutions to manage railway networks equipped with mixed signalling systems (the foreseen future scenario).
- To help railway authorities in deciding where to apply new signalling systems and quantifying expected benefits.

5. References


COMBINE – enhanced COntrol centre for a Moving Block slgNalling systEm, D5.2 Criteria of traffic regulation in moving block, Document code WP-5/D/13/01/1/f, European Commission, Telematics Application Programme, Sector Transport, Project number TR 4004, (2000).