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Railway driver advice systems: Evaluation of methods, tools and systems

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ABSTRACT

This paper assesses solution alternatives for railway driver advice systems. To do so a two stage assessment procedure is adopted. First, a wide range of existing systems is identified, using a basis of scientific literature and input from a field survey. Next, the reviewed systems are evaluated using a set of criteria, like: distribution of intelligence, processing unit integration, driver interface, positioning system and communication requirements. The above provides a clear structure for the assessment of DAS, aiming to identify which systems should be investigated in more detail as potential components of real-world deployment. The results highlight major differences in the way that intelligence and processing capabilities are distributed between the control center and the train. They also highlight different approaches to the integration of driver interface, train positioning systems and communication technologies that facilitate the exchange of information between the track and the train. The decision to embark on one of the various approaches depends not only on algorithmic issues but also on human factors considerations, the limits of technology and the costs of upgrading it. Practical aspects such as technical and spatial characteristics of the driver's cabin, context and format of the advisory information are also of importance.

1. Introduction

Modern railways face growing demand but without a matching increase in capacity, which results in rail networks being more and more saturated. The demand for capacity improvement calls for optimization methods to tackle the railway capacity problem of limited infrastructure. These methods include, among others, providing the train driver with additional information to optimise train movements within the limits imposed by the signalling movement authorities (Mitchell, 2009). With a view to simplicity and safety, signalling systems tell the driver how far and fast the train can safely proceed within the allocated movement authority, but the wider traffic management picture is hidden from the driver. To achieve higher levels of punctuality an in-cab system could be installed which continually advises train drivers of the train's time with respect to the published timetable. These systems are called Driver Advice Systems (DAS) and provide all the necessary functionality to calculate and deliver drivable advice to the train cab, on the basis of conflict-free time targets which are set outside the system's boundaries and are communicated to the DAS in a synchronous or an asynchronous fashion. According to this definition, the system's fundamental requirements are:

- To provide information to the driver about the target arrival time at certain waypoints along the route in order to satisfy the timetable and avoid conflicts with other trains.
- To monitor the movement of the train so that the advice is properly updated and target times are achieved.
- To calculate an energy-efficient speed/distance profile to achieve the target times (optional).

A thorough literature investigation has revealed that many automated driver advice systems have been trialled and some are in use today by European and other railways. DeltaRail Group (2009) gives a list of existing systems and provides an interesting discussion of their technical and human-related features and characteristics. It stems that the majority of these systems assume reactive driving to achieve the diptych: safe and timetable pursuant train movements, with energy saving being a desirable feature (Albrecht, 2005, 2009). For passenger trains in particular, adherence to the timetable is regarded the most important consideration after safety (Hamilton and Clarke, 2005; Roth and Mutter, 2009). Moreover, the current trend in persuading drivers to be more timetable compliant is to make them aware of the traffic situation near or around their trains rather than to provide advisory information, exclusively, about one's train (Tschirner et al., 2013).

Extensive research into this topic has been done also by the industry, but the precise details of each alternative design and practical implementation are likely to be confidential and thus, difficult to obtain as it is the key competitive differentiator between the products in the market place.

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Unlike the research on DAS technical designs and implementation, relatively more research has been put into the topic of energy efficient driving, which is an optional feature for most of the existing advisory systems. A lot of effort in this topic has been concentrated on the calculation of an energy-saving speed profile and on the possible ways to communicate the advisory information to the driver (Albrecht, 2013; Howlett et al., 1994). Other relevant work in this area has identified smart driving techniques where quick wins can be made in terms of energy-saving (Liu and Golovitcher, 2003; Lukaszewicz, 2008).

Besides the above, the literature is surprisingly sparse in describing how driver advice systems could be implemented, or in detailing the challenges inherent in their integration with other railway systems. Even at the strategic level, it is not clear what the extent of the DAS functionality should be, or what factors to consider when deciding on the technology mix or on the form of the delivered advice. This silence in the literature prompted our research. This paper covers the basic methodological steps followed to assess the state-of-art of railway driver advice systems and draws some initial conclusions on the appropriateness of the most common system configurations. The work includes: survey of existing driver advice information systems, discussions with stakeholders, review of the driving needs and characteristics including technical and human factor issues, assessment of options for task distribution, train installation and driver interface and finally, formulation of recommendations for further study.

The basic findings of the research suggest that the implementation of a driver advice system is technically and operationally feasible on European railway networks; performance and capacity benefits are expected in some locations but these are difficult to quantify; the safety impact is expected to be neutral or positive. Thereafter, preferred options are proposed for task distribution, train fitment and driver interface, but it is recognised that, unless the key Traffic Control Centre (TCC) to train interface is defined, there may be a range of solutions for different types of rolling stock and train services.

This paper builds on the research project ONTIME "Optimal Networks for Train Integration Management across Europe", and more particularly on the research for Driver Advice Systems (DAS). The objective of this research is to develop and assess an integrated engineering and operational approach to improve railway traffic management, using advisory information to increase network capacity without reducing the service quality. The research has been undertaken with support from a stakeholder group representing European Infrastructure Managers, DBNetz (Germany), ProRail (Netherlands), RFF-DCF (France), SBB (Switzerland), RFI (Italy), Trafikverket (Sweden) and Network Rail (UK).

2. Understanding advice systems

The analysis below defines the context in which a railway driver advice system should operate. This context is delineated by a series of determinants which need to be clearly understood before analysing current practices and technologies. The most important determinants which are tackled by this paper include: driver needs and characteristics, driver-train interaction, and technology compliance.

2.1. Driver needs and characteristics

While driving the train, the driver's primary goals are to (Rail Safety and Standards Board, 2002a,b):

- Ensure safety (this duty takes priority over all other duties).
- Maintain the schedule of the service (as far as possible), and if the above are covered.
- Improve energy efficiency of service delivery and passenger comfort, while respecting standard operating procedures set by the RU (this depends on the operator and driver but also on traction and the ability to meter energy consumption).

To meet these objectives the driver must drive the train in a safe and efficient manner, which means:

- Collecting and recalling from route knowledge the current and future speed targets that apply to the service – such targets come from a variety of sources, grouped into infrastructure, regulation and operational factors.
- Selection of the appropriate train speed, i.e. adopting a speed that does not exceed the various speed restrictions (or otherwise compromise safety), and is sufficient to achieve the service timetable (or minimise delay).
- Monitoring the speed of the train by collecting information from the speedometer and various sources (visual perception of speed, cab noise, and motion).
- Comparing the appropriate speed with the train speed. When the train speed does not match the required one the driver identifies the difference, usually represented as a time or speed gap.
- Using the difference between the required and the actual speed to control the train speed by changing the settings of the power or brake controller, also taking into account various handling factors that affect the train's response (gradients, curves, railhead conditions) and regarding the requirements of the driving practices (such as the professional driving policy).
- The speed control activity changes the speed of the train so that the difference between the target speed and the train speed is minimised.

Operating the train in this way requires the driver to continuously monitor the progress of the train against a series of passing marks and scheduled stops. Without driving advisory/support, the drivers have no guide about progress within the schedule, and only route knowledge and experience allow the driver to judge if the service is running early or late between two timing points. Any temporary speed restrictions within a route, while reflected in the timetable, make the driver's judgements about progress and recovery time more difficult.

2.2. Driver-train interaction

Integration of the train driver into the DAS design is a multistage activity (Dekker, 2008). This paper will define the framework and the principles for the consideration of human factors in order to help the designers to consider the requirements, capabilities and preferences of the human operator and therefore, to facilitate (or remove obstructions to) his integration. This application framework has the following features:

- *The context of operations:* How DAS is to be used, the capabilities and constraints of the system, and the reactions that these cause to the drivers.
- *Integration of human operator:* How the design of the system should make use of the particular characteristics and constraints common to all drivers from their human psychology, anatomy and physiology, and also give consideration to the relationship of the human factor with issues like safety and interaction with legacy TMS, etc.