The Future of Railway Traffic Management

Rail Traffic Rescheduling under Moving-Block Signalling

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Worldwide, railways are experiencing a continuous increasing travel demand. Existing railway networks have limited capacity and practically no extension possibilities due to the costly and land-consuming infrastructure. Next-generation signalling systems such as the moving-block system are being developed as an alternative way to fulfil future railway demand. These systems rely on decreasing the separation between trains to increase the network capacity.

In conventional fixed-block signalling systems, the track is divided into block sections of fixed length. These blocks are protected by trackside signals, indicating whether an approaching train can proceed, needs to brake, or has to stop. With this, fixed-block signalling ensures safe train separation based on pre-set numbers of blocks representing overall worst-case braking distances.

In moving-block signalling systems, minimum train separation is based on absolute braking distances, the distance a specific train needs to reach a standstill from its current speed. This requires continuous braking curve supervision, which is enabled by on-board train positioning and integrity monitoring, and bi-directional vehicle-to-infrastructure radio communication.

The signalling system in place is crucial for the execution of rail operations, which is supported by railway traffic management. Railway traffic management is responsible for the monitoring and prediction of traffic, as well as the detection and resolution of conflicts. In case of conflicts, railway traffic management has to take rescheduling measures to minimise the delay propagation in the network.

In current practice, human dispatchers take rescheduling measures based on experience and pre-set rules. These decisions are not necessarily minimising delay propagation from a mathematical perspective as they are neither customised to the specific traffic state nor taking into account the possible effects on the future state. With the aim to support human dispatchers in taking optimised decisions, but also to move towards (partial) automation, rail traffic rescheduling models are developed.

Existing rail traffic rescheduling models mostly refer to the conventional fixed-block signalling system. Investigation of the applicability of existing models to moving-block signalling leads to the identification of the main challenge in the development of a rail traffic rescheduling model for moving-block signalling: modelling the dynamic, train-specific and speed-dependent headway separation. The ability of a model to describe the moving-block headways depends on the representation of the infrastructure and the considerations of speed dynamics. Existing rescheduling models rely on the fixed-block infrastructure discretisation, while in the moving-block systems infrastructure is considered as a continuous space. Similarly, existing models include speed dynamics to a limited extent. Either fixed speed is assumed or discrete speed decisions are considered, while continuous speed is crucial for the modelling of the characteristic speed-headway relation.

Two main research directions are proposed to bridge the gaps in the development of a rail traffic rescheduling model for moving-block signalling. The first direction is a discrete modelling approach. Existing rescheduling models can be exploited by introducing a finer discretisation of the infrastructure that is independent of block sectioning. Either discrete or continuous speed decisions can be introduced depending on the model formulation. The second direction is a more continuous approach. In train trajectory optimisation, dynamic systems are used to describe the speed-headway relation. With this, railway operations can be modelled by dynamic systems, in which both space and speed are dynamically described. However, train trajectory optimisation models are mostly limited to single trains due to the resulting complexity of multi-train models.

In line with the first research direction, we propose to enhance an existing fixed-block and fixed-speed rescheduling model by introducing a finer discretisation, continuous braking curve supervision and speed levels as follows. The track is divided into switch areas and open line stretches. A switch area consists of one or more switches, which are modelled as conventional fixed blocks. An open line stretch connects two switch areas and is discretised into block-independent sections of which the entry points are considered. Speed is introduced by speed profile options corresponding to a target cruising speed, e.g., the maximum or the scheduled speed. Train operation times and minimum separation distances are derived for each entry point for the different speed profiles. In Figure 1, this modelling proposal is illustrated.

This proposal will lead to a rail traffic rescheduling model based on an approximation of moving-block rail operations. Though not fully capturing the moving-block characteristics, it contributes to the development of a rail traffic rescheduling model for moving-block rail operations as follows.

- The train separation is based on absolute braking distances, derived from passing speeds corresponding to realistic speed profiles.
- Continuous braking curve supervision is modelled through the consideration of the brake indication point.

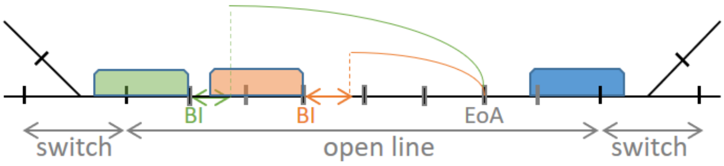

Figure 1: Illustration of proposal on the modelling of rail traffic under moving-block signalling. The open line is discretised into small sections. The end of movement authority (EoA) is based on the last cleared discrete point and the brake indication point (BI) is determined based on the braking curve of the approaching train following either the maximum (green) or the scheduled (orange) speed profile.