

# A Microscopic Model for Railway Operations Research: Integrating Choices of Routes, Order and Speed of Trains

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Railway operations comprise a special scheduling problem: Consider trains as jobs to be processed by pieces of the railroad infrastructure. Now, any machine can only take on a new job some time after its previous job has been taken over by another machine, without storage and without partial processing. Furthermore, the minimum and maximum time a job can take to process depend not only on characteristics of the individual jobs and the individual machines, but also on an additional sort of state that the job is in: the train's current speed, which in turn depends on its past few processing steps. Depending on the infrastructure modelling, additional constraints arise from the interlocking as either certain pairs of machines unable to be processing at the same time, or the jobs requiring sets of collaborating machines rather than one single machine at a time.

Thus, traditional scheduling models and algorithms are not applicable. Many special models have been introduced in the literature; however, most of them make one or more simplifying assumptions, such as coarse discretisation of time, neglect of the interplay between time and speed, or fixed paths.

I will discuss and illustrate my attempt to formulate an integrated, exact microscopic model in which

- the classic (German) railroad interlocking system is represented,
- trains can be re-routed both macroscopically (i.e., via entirely different lines and stations) and microscopically (i.e., on another track, which also allows for overtaking with or without stopping), and
- the physics of speed are respected and utilised.<sup>1</sup>

The price I am paying for the level of detail is, naturally, generic MIP solvers rendered unable to find proven optimal solutions within reasonable time even for small instances. I will also present a brief case study on different MILP and MIQCP formulation variants and their performance in Gurobi 6.5 and Cplex 12.6.

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<sup>1</sup>Disclaimer: I am still simplifying in some particular details.