CA: B1 Topic: Multimodal Vehicle Integration and Charging Infrastructure
Code: D2-B1.1.2: Technical simulation and management of more efficient transport systems

Nowadays, energy efficiency is a key requirement for railway systems in order to reduce operating costs. One of the main solutions for implementing energy efficiency is the optimization of train speed profiles to minimize tractive energy consumption. From a transportation systems point of view, the feasibility of optimized speed profiles must consider the possible impact on rail traffic, in order to evaluate their feasibility. To do so, an innovative optimization framework for the definition and the evaluation of energy efficient speed profiles, based on supply design modelling, has been proposed. The framework operates on two levels: the first level generates energy efficient speed profiles with respect to timetable constraints, infrastructure characteristics and rolling stock features, and the second simulates these speed profiles on the rail network within the specific rail traffic conditions. Through this new integrated view, the evaluation of the proposed optimal speed profiles can fully take into account the operational requirements of the services, such as trains scheduling, absence of or small allowance for delays and respect for buffer times for passenger transfer at connecting stations.

With the use of onboard monitored data related to energy consumption, it has been possible to better identify the train motion phases during the journey, and to provide additional information for the calibration of the train motion models. The estimated speed profile, obtained with the calibrated model, can be used as a reference for further considering potential energy savings and defining possible energy saving strategies. Considering real on board data of a freight train used as case study, the energy saving speed profile allowed a potential saving up to 11.5% of energy, depending on real operating conditions and specific driving strategies (e.g. coasting, no coasting). Alternative speed profiles can be built, starting from rail traffic monitoring. In the freight train case, it is possible to find an appropriate time slot for departure in order to generate a speed profile with a unique value of speed and without stops.

Considering timetable modification, additional benefits can be considered. Rescheduling processes, i.e. the modification of scheduling in real time, for conflicts prevention, delay recovering and impacts mitigation of disturbances and minor disruptions, can generate optimal solutions which are also energy efficient, for example by reducing the number pf unplanned stops. It is worth to consider that increasing automation in the rescheduling processes is a key innovation for increasing capacity on existing railway networks and optimizing energy consumption. The set of feasible solutions is much higher than set of solutions considered by human dispatchers that are usually defined by internal regulations of the companies, thus a larger set of solutions can only be explored and managed by increasing the degree of automation.

The consideration of energy efficiency in rescheduling models requires that the models fully include the microscopic attributes of the network (e.g., track gradient). Therefore, this research only considered mathematical models that include a microscopic representation of the network. The most common types of these models are the Alternative Graph, the Flexible Path, and the Resource Conflict Graph (RCG). The proposed rescheduling model is based on an RCG model, already specified and applied both for rescheduling and for scheduling with energy consumption optimization. The proposed model adapts the RCG to include energy efficiency in the rescheduling procedure. Thus, the resulting model minimizes energy consumption, delays, and cancellations in a single step.

The proposed model was tested in a numerical experiment at the ETH's Railway Operations Laboratory. In these tests, trajectories were generated using simulation-based approaches and were used as control variables. The rescheduling code completed its elaboration within few seconds and in all cases, the rescheduling procedure returned the new schedule before the affected trains started to move. However, the computation time grew quite fast with increasing the number of variables. The potential energy savings in this case resulted to be up to 9%.

The research results suggest taking an integrated approach to further model development by including speed profile optimization and rescheduling in a comprehensive environment.