Scientific Report for STSM on "Optimal Electric Load Managament for Rail Traffic"

Andreas Bärmann[1]

[1]Andreas.Baermann@math.uni-erlangen.de

Applicant: Dr. Andreas Bärmann, FAU Erlangen-Nürnberg, Germany
Host: Prof. Dr. Juan-José Salazar-González, Universidad de la Laguna, Tenerife

1 Purpose of the STSM

The motivation for this STSM has been to establish a cooperation between the applicant, Andreas Bärmann, and the host, Juan-José Salazar González on an interesting optimization problem at the interface of logistics and energy planning. A large part of the energy cost of a railway, metro or tram operator depend on how well his energy consumption is balanced over time, i.e. if are there high peaks in consumption relative to the mean consumption over the planning horizon, or not. We had already shown in a publication (see Bärmann et al. (2015)) that there is significant potential for cost saving by improving the load management via optimized timetables that avoid too many simultaneous departures. This STSM was conducted with the purpose of working on possible model formulations to transfer these results from static optimization (in the planning phase) to dynamic optimization (in real-time) in order to lay the groundwork for a joint European Horizon 2020 project proposal.

2 Description of the work carried out during the STSM and the main results obtained

The first part of the STSM was devoted to introducing to the host our previous work on the topic. In Bärmann et al. (2015), we have already established a basic model formulation for the problem of reducing the load-based energy cost of a rail transport company via an adaption of the tentative timetable towards the end of the planning phase. The optimization problem takes the form of a project scheduling problem, which is possible because of the assumption that the order of the departures of the trains from the stations does not change with respect to the tentative timetable. Furthermore, we introduced our extension of this work to improve the model formulation such that the set of feasible timetables can be described via a totally unimodular constraint system in binary variables, which is currently in the state of a working paper (Bärmann et al.

(2016)). The elaboration on our previous work also included a talk on our results so far which I gave as a part of a seminar on combinatorial optimization at the chair of my host.

The next step was to study the data on the problem we had received in the maintain from our industry partner VAG, the local public transport operator in Nürnberg, Germany. We studied the structure of the metro timetable that is to be optimized as well as the data on the power consumption of the metro trains. This gave us some initial ideas on how our current model formulations have to be adapted and extended and how we could process the data to make it usable for our purpose.

It became clear rather quickly that an important step to make our models useful for decisions involving real-time reschuling is to include speed optimization in the model. That means that now we do not only optimize the departure times of the trains from the stations, but also their speed profiles when driving from one station to another. We thus developed a model extensions that allows for this additional feature.

The next question then was if the new model can be reformulated again to obtain a totally unimodular description of the feasible set. Thus, we began to conduct polyhedral studies using *porta* based on small example instances. This led to the impression that a totally unimodular reformulation is again possible as well as a first idea what it can look like. We would like to continue this research after the STSM.

3 Future collaboration with the host institution

As indicated, we would like to understand the new problem better in order to find better model formulations and to be able to solve the problem on real-world instances. Thus, we will continue our collaboration on this topic, if possible in the form of a joint European project, for which we want to apply jointly.

4 Foreseen publications resulting from the STSM

Our plan is to continue the joint research on the STSM topic and to publish the result in one or several journal articles.

5 Confirmation by the host institution of the successful execution of the STSM

See the letter attached.

References

Bärmann, A., Gellermann, T., Merkert, M., and Schneider, O. (2016). Multiple-choice problems under staircase compatibility and their applications in scheduling and gas routing. Technical report, FAU Erlangen-Nürnberg. Working paper.

Bärmann, A., Martin, A., and Schneider, O. (2015). Optimal balancing of the power consumption of trains in a railway network via timetabling. In *Proceedings of CASPT 2015*.