A Multi Criteria Analysis Framework

For Railway Timetable Quality

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Extended abstract.

Railway traffic has worldwide an increasing trend, and especially in industrialised countries the demand for travelling and transporting with the railway mode has increased significantly during the last decades. Railway traffic is known to be environmental friendly and energy efficient and the trend is welcome and has a strong political support. In many countries, however, the increase in traffic volumes is not fully met by extensions of the infrastructure.

UIC (2004) has qualitatively described the capacity on a given infrastructure in terms of the interdependencies between *number of trains*, *average speed*, *stability* and *heterogeneity*. The possibility to increase the number of trains is available to the price of increased speed, reduced stability or reduced heterogeneity.

In this work we use the event-based Mixed Integer Linear Programming model suggested by Törnquist and Persson (2007) to describe the timetabling problem, where integer (binary) variables define the train order, i.e., the order in which trains are utilizing common infrastructural resources, and time variables are continuous. When the timetable is dense and the train order is given, the flexibility for the continuous variables is limited. Here, we want to evaluate a given train order, in the sense that we compute and compare its most extreme realisations. The remaining Linear Programming problem is easily solved, and we can use dual prices to identify which train order decisions that are critical.

Events included in this model represent train activities (driving and scheduled stopping) as well as technical time separation between consecutive trains using the same infrastructural resource (minimum headway and clearance time). Each event has a minimum duration and all events together form an event graph, similar to the existing graphical timetable but with explicit representation of the technical time separation. We are interested in finding those events in the graph, which are critical for maximizing various goodness criteria.

We show that computing the *capacity utilisation*, in the way it is described by the UIC 406 method (UIC, 2004) is identical to the problem of determining the critical path in the event

graph. The events included in this path are decisive for the capacity utilisation and it is impossible to reduce capacity utilisation unless one of them is removed or rescheduled.

If instead, we fix the start time for the first event, and the end time for the last event, respectively, and increase all activities for the trains proportionally, until no more increase is possible, we have identified another critical path, which is decisive for the *robustness*, assuming that all time separation is fixed and insensitive to disturbances. This coincides to the robustness definition used by Goerigk and Schöbel (2014).

Analogously to this, we can instead fix the duration for all train activities and instead increase the duration for all time separating (technical) activities proportionally. We argue that, the more homogenous the timetable is, the more could the duration of these activities be extended. Thus, the resulting critical path give information about what activities that should be removed or rescheduled to increase homogeneity. (In a strict meaning, however, the heterogeneity of the timetable is a result of the train order, which is kept fixed in this analysis framework.)

Finally, we can minimize the total time spent by all trains in the timetable. This analysis will not form a critical path, but can help in identifying events where an increase of the travel time is meaningless and will be compensated by waiting for other events.

Clearly, none of the four extreme realizations of the train order gives a useful timetable. But the analyses can be of great value when it comes to identifying trains or train activities to remove or reschedule for improving the timetable quality. Likewise, we can identify sections in the infrastructure, where increasing speed and/or an additional track are interesting. We can also use the framework in the ad-hoc process to identify where to insert an additional train, without disturbing existing traffic.

In the future, the framework may be extended by introducing additional activities representing connections between trains, where a minimum interchange time must be respected. It is also possible to introduce commercial headway separation, ensuring that trains of a certain type (e.g., commuter trains) are separated with a fixed time. This type of activities will form a (partially) periodic timetable.

References:

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