PASSENGER ORIENTED ROLLING STOCK RESCHEDULING

Decision making on stopping patterns

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ABSTRACT

Railway operations are disrupted frequently. The disrupted situation requires to adapt the timetable and the resource schedules quickly. This research focuses on the rescheduling of rolling stock. Disruptions have a large influence on the passenger flows. The rolling stock schedule must be adapted such that there is on every train enough capacity for the modified passenger flows. To handle the modified flows it may be beneficial to adapt the stopping patterns of intercity trains to allow stops at regional stations. In this research we study a real time rolling stock rescheduling approach which determines if additional stops at regional stations are worthwhile.

KEYWORDS

Rolling Stock, rescheduling, disruption management, additional stops, passenger flows

INTRODUCTION

Passenger railway operations often face unforeseen events like infrastructure malfunctions, accidents or rolling stock breakdowns. As a consequence, parts of the railway infrastructure may become temporarily unavailable. Therefore, it may not be possible to operate the timetable as planned. Within minutes, or even better, seconds, new schedules must be constructed which is called real-time rescheduling. Jespersen-Groth et al. (2009) describe disruption management as the accomplishment of three interconnected steps: (i) Timetable adjustment, (ii) rolling stock rescheduling and (iii) crew rescheduling. Due to the complexity of the process and the limited time available for decision making, these steps are carried out sequentially in practice. First, an adjusted timetable is constructed by canceling, delaying or rerouting trains. Thereafter modified resource (rolling stock and crew) schedules are constructed. We will focus on the rolling stock rescheduling.

If certain trains are canceled due to a disruption, the passenger flows react to the changes in the system. The passengers which had planned to take a train which is now canceled have to cancel their trip or to find another route to their destination. This means that the disruption has caused additional demand on the trains of the alternative route. In response to that the railway operator has to arrange additional capacity on the alternative route. Therefore a rolling stock rescheduling approach to handle a disruption must take the modified passenger flows into account and not the flows of a regular day. Sometimes the modified flows ask for a lot of additional capacity on regional station. One way to handle this is to increase the capacity of the regional trains, but another option is to let intercity trains make additional stops at some regional stations. These additional stops will delay the intercity trains with a few minutes. This means that the original passengers of the intercity trains will get an additional delay in favor of reducing the delay of the passengers at the regional station. The railway operator has to make tradeoffs between the consequences for the different passengers. This means that also the influence on the transfer possibilities of the passengers must be taken into account.

Our research focuses on constructing a fast rolling stock rescheduling approach. Next to rolling stock decisions the approach will also make some minor timetable decisions if necessary. It is allowed to let trains make additional stops at certain stations if the predicted passenger flows require that. For this research we assume that the additional delays caused by the modified stopping patterns will not influence other train traffic. The possibility to change the stopping patterns will make the rolling stock rescheduling more passenger oriented and will increase passenger satisfaction during disruptions.

LITERATURE

There is some research on rolling stock scheduling (e.g. Fioole et al 2006) but on rolling stock rescheduling there is far less research done. Nielsen et al. (2009) started with constructing a rolling stock rescheduling approached. This approach is very much focused on the logistic aspects and tries to reschedule the rolling stock in such a way that the regular passenger flow can be accommodated. Nielsen (2010) improved this approach by taking the modified passenger flows into account. However this approach does not allow modifying the stopping patterns. Our research extends the approach of Nielsen (2010) by allowing that the stopping patterns of some trains may be modified.

MATHEMATICAL MODEL

Disruption management consists of adapting the timetable and the resource schedules. We focus on rolling stock rescheduling and assume that the timetable is already adapted and that after we have constructed a new rolling stock schedule the railway operator can find enough crew for every train.

In the modified timetable some trains have been cancelled and some new trains have been added to deal with the disruption. The original rolling stock schedule has become infeasible for the modified timetable. Rolling stock units who had to run a canceled train cannot finish their duty anymore. Moreover, rolling stock must be assigned to the new trains. The operator often has some rolling stock available at shunting yards to deal with those canceled and new trains.

The operational rolling stock rescheduling problem has as objective to find rolling stock for as many trains as possible. Moreover the total capacity of the rolling stock of a train must match the demand of that train. If the train has less capacity than there is demand for, some passengers have to remain at the station and wait for the next train. Or even worse, if there is no rolling stock at all for the train, the train has to be canceled. In the objective function

tradeoffs must be made between operational cost and delay of passengers caused by too less capacity.

Both the rolling stock schedule and the passenger flows are dependent of each other. The rolling stock schedule must be based on the passenger flows but on the other hand the passenger flows will change based on the rolling stock schedule. Therefore an iterative procedure is suggested in which the rolling stock rescheduling problem and the passenger flow estimation problem are solved several iterations after each other. Solving those problems must be done very quickly since we deal with a problem which must be solved in real time. Each iteration has three steps: i) First a new rolling stock schedule is constructed based on the estimated passenger flows. ii) Secondly, a simulation model predicts the modified passenger flows based on the new rolling stock. iii) Feedback about the new predicted passenger flows will be used for adapting the stopping patterns and for determining an optimization direction for the rolling stock rescheduling problem in Step i) of the next iteration.

In Step i) the rolling stock rescheduling problem is solved with the composition model of Nielsen (2010) by taking the latest predicted passenger flows into account. Note that the rolling stock rescheduling problem is not just an assignment problem but also a problem of determining the order of trains in a composition. See also, Fioole et al (2006).

Since it can still be that some trains do not have enough capacity, not all passenger can take their preferred route. In Step ii) is simulated how the passengers are divided over the trains and whether some passengers have to cancel their trips or not. First the routes the passengers can take are determined by using directed graphs in which the arcs represent the trains of the modified timetable and the transfers. The nodes represent the arrivals and departures of trains. If the source and the sink represent respectively the origin combined with a departure time and the destination combined with a ultimate arrival time of a passenger then in the graph a path from source to sink represents a route the passenger can take. We assume that passengers take the fastest route. However because of capacity limits not always everyone can take his fastest route. Then the simulation model will assign some passengers to other routes. The predicted passenger flows by the simulation model are the input for the adaptation of the stopping patterns and the optimization direction for Step i) in the next iteration. Note that the graphs are dependent on the decisions made on the stopping patterns, since trains can be delayed and transfers can have become feasible or infeasible by the additional stops.

CONCLUSIONS

In several cases it seems worthwhile to adapt the stopping patterns of trains during disruptions. Also just after the end of a disruption modified stopping patterns are very useful to pick up passengers at stations where it was not possible to stop during the disruption. For some people the changed stopping patterns lead to additional delays and missed connections but others profit from it by having less delay. We made a rule determining in which cases the additional delay of a train caused by an additional stop at a certain station is justified by the reduction in delay of the passengers at that station.

In further research this rolling stock rescheduling approach can be tested on real world instances. The approach can be extended by applying delay management decisions. In delay management, decisions are made whether a train has to wait or not on passengers of other trains who want to transfer to it. With delay management one could control part of the passenger flows.

REFERENCES

Fioole P.J., L.G. Kroon, G. Maróti, A. Schrijver (2006) A rolling stock circulation model for combining and splitting of passenger trains, in: *European journal of Operational Research*, Volume 174 (2) , pp 1281-1297.

Nielsen L.K., G. Maróti (2009) *Disruption Management of Rolling Stock in Passenger Railway Transportation*, Technical Report ERS-2009-046-LIS, ERIM Report Series Research in Management, Rotterdam.

Nielsen L.K. (2010) *Rolling Stock Rescheduling in Passenger Railways – With Applications in Disruption Management and Short-term planning*, PhD thesis, Erasmus University Rotterdam, Rotterdam, *DRAFT*.

Jespersen-Groth J., D. Potthoff, J. Clausen, D. Huisman, L.G. Kroon, G. Maróti, M. Nyhave Nielsen (2009) Disruption Management in Passenger Railway Transportation, in: Ahuja R.K., R.H. Möhring and C.D. Zaroliagis (eds.) in: *Robust and Online Large-Scale Optimization*, Springer, Berlin, pp. 399-421.