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Publication Date:
2017

Permanent Link:
https://doi.org/10.3929/ethz-b-000210340

Originally published in:

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Discussions of the reschedule process of passengers, train operators and infrastructure managers in railway disruptions

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Abstract

In case of railway disruptions, the whole railway traffic will be impacted in a large area and for a long time. There are three stakeholders in railway disruption management process that cannot be neglected: passengers, train operators and infrastructure managers. Infrastructure managers are mainly responsible for operational feasibility of the rescheduled timetable. Train operators aim at minimizing operation costs and maximizing the services offered to passengers. Passengers’ needs are an important evaluation for rescheduled timetable in railway disruptions. Since the three stakeholders have diverse and even conflicting objectives in the disruption management process, how to handle the trade-offs of these objectives deserves further discussion. This paper summarizes the possible methods to solve the holistic rescheduling process including passengers, train operators and infrastructure managers in railway disruptions. Specifically, this paper discusses two reschedule process and compare their pros and cons. This research links passengers, train operators and infrastructure managers in the rescheduling process of disruption management. It is the base for solving the trade-offs of different objectives of stakeholders.

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Peer-review under responsibility of the scientific committee of the 20th EURO Working Group on Transportation Meeting.

Keywords: Disruption management; passenger satisfaction; timetable rescheduling; rolling stock rescheduling

1. Introduction

There are three main sub problems in railway disruption management (Jespersen-Groth et al., 2009): timetable adjustment, and rolling stock and crew rescheduling and summarise the roles and objectives of infrastructure managers.

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and train operators. From the network viewpoint, infrastructure managers are responsible for network traffic control while train operators are for rolling stock schedule and crew schedule. From station viewpoint, infrastructure managers are responsible for train routing and platform assignment while train operators are for shunt planning. As described in Cacchiani et al. (2014), there are papers dealing with the integration of different phases of real-time railway rescheduling, with the aim of determining a good new schedule for the timetable, and the rolling stock and crew duties when a disruption occurs. In this paper, we omit the quotes of the literatures according to crew rescheduling.

Current research with regard to disruption management is mainly from operations-centric views. The main problem in railway disruption is to reschedule the timetable, which is generally obligated by infrastructure managers. The most popular objective is to minimise train delays (e.g. Brucker et al., 2002). There are also some extending variations to describe train delays more precisely. For instance, Albrecht et al. (2013) propose two criteria to measure the rescheduling objectives. The one is the minimum total delay, consisting of train delays and the maintenance delay, while the other is to minimise the maximum train delay, avoiding largely attributed delay to one single train. Narayanaswami and Rangaraj (2013) minimise the weighted sum of the difference between the actual and scheduled arrival time at the destination for all trains on both directions of a single track. The second wide-applied objective is to minimise the deviations from original timetable. For example, Hirai et al. (2009) aim at minimising the number of stops outside stations and the deviations from original timetable. To avoid the modifications of scheduled timetable, some papers propose minimising the number of cancelled trains as one objective. Zhan et al. (2015) and Veelenturf et al. (2016) minimise the number of cancelled trains and the total weighted delay. Except minimising the delays of the operated trains and the number of cancelled trains, Louwerse and Huisman (2014) include another two objectives from the operation viewpoint: balancing the number of trains in both directions, and distributing the operated trains evenly over time. The former objective is specified by the absolute difference between the numbers of cancelled train sub series in each direction while the latter one is demonstrated by the maximum time between two operated trains in the same direction.

In addition to timetable rescheduling, the train operating companies need to reschedule the rolling stock at reasonable cost, and then to adjust the crew schedules. The literature review in this section mainly focuses on rolling stock rescheduling. The prime objective of train operating companies is to minimise the operation cost. Sato and Fukumura (2012) seek to minimise the total sum of the costs of selected paths. Budai et al. (2010) not only use carriage-kilometres, seat shortage kilometres and the number of composition changes as additional objective, but also propose to resolve as many off-balances as possible in the rescheduling process. Besides, Nielsen et al. (2012) measure the deviation of the rescheduled circulation from the original circulation by employing three objective criteria: cancelled trips, changes to the shunting processes, and off-balances.

Jespersen-Groth et al. (2009) proposed that one important objective of the operators in the disruption management process is to minimize the number of passengers affected by the disruption, and to minimize the inconvenience for the affected passengers. However, literatures are from passenger-centric views to deal with disruption management are much scarcer than that from operations-centric views. Binder et al. (2016) focus on passenger oriented timetable rescheduling in railway disruptions and integrate three objectives: passenger satisfaction, operational costs and the deviation from the original timetable. The passenger dissatisfaction is given by the generalised travel time including in-vehicle time, waiting time, numbers of transfers, early arrival and late arrival. The operational costs refer to the running cost of original trains as well as emergency trains. The deviation from the original schedule is a weighted sum of the different rescheduling possibilities: cancellations, re-routings, delays and the cost of adding an emergency train. Almódovar and García-Ródenas (2013) study the rolling stock rescheduling for passenger railways in case of emergencies and minimise the total in-system time of the passengers. The objective function in Kroon et al. (2015) consists of two parts: the system-related costs and the service-related costs. The system-related costs refer to three penalties: modifications in rolling stock compositions, modifications in the shunting operations and end-of-day off-balances. The service-related costs refer to the sum of the individual inconveniences, considering the increase of passenger delay under the limits of train capacity. Cadarso et al. (2013) integrate the timetable and rolling stock rescheduling in disruption management and propose an integrated objective consisted of seven terms: operating costs of planned and emergency services, operating costs of empty movements, composition changes, cancellation of services, denied passengers, deviation from the schedule of commercial services, deviation from the schedule of the empty movements. Especially, the last two terms hint to minimise the length of the recovery period. The objective
function in Veelenturf et al. (2014) consists of system related costs for the timetable adaptation and the rolling stock rescheduling, and costs for the passenger delays.

In order to balance this different objectives listed in railway disruptions, how to dealing the relationship of passengers, train operators and infrastructure managers needs to be answered. This paper is structured as follows. Section 2 reviews the current research about disruption management and summarizes the main methods solving this problem. Section 3 proposes the possible ways to dealing with disruption management and discusses the pros and cons of each rescheduling procedure. Section 4 concludes the main contribution of this work.

2. Methods to handle disruption management

2.1. Integrated model

The common integrated disruption or delay management process is to combine timetable rescheduling and rolling stock rescheduling as an integrated model. The typical integrated model from operations-centric views is the mixed integer programming (MIP) model. Fekete et al. (2011) focus on disruption on subway networks and establish the integrated model to reschedule the timetable and rolling stock. The integrated model is applied in Vienna’s subway network and the computation time is feasible enough to obtain practical close-optimal solutions. But railway disruptions can be more complicated due to the complexity of railway timetables, whether the integrated model can be applied and how detailed it can reflect the real practices in railway disruption management are still discussable. Adenso-Díaz et al. (1999) focus on the large delay management problem in railways. The integrated optimization model combing timetable and rolling stock rescheduling appears to be too large to be holistically solved. The heuristics backtracking method is applied to find feasible solutions. From this paper, one conclusion can be summarized is that the complexity of solving the integrated model is high. Also, these rescheduling tests don’t contain detailed passenger information. For example, the precise numbers of passengers on trains and their destinations are not available in real-time. If we include passenger information, what is the rescheduling process? Cadarso (2013) include additional trips, cancelling trips and possible allocation of rolling stock as the tools to handle railway disruptions. The integrated model contains not only the timetable and rolling stock rescheduling, but also the passenger dynamic model which is demonstrated by the Logit model. This paper is a taste of the integrated model of passengers, train operators and infrastructure managers. But some assumption mentioned in this paper is simplified. To apply this integrated model in practice still needs further research.

2.2. Distributed model

Compared to the integrated model, another feasible methods to solve the trade-offs of passengers, train operators and infrastructure managers are the distributed model. That means using the iterative procedure of timetable rescheduling, rolling stock rescheduling and passengers model to solve the problem interactively. Veelenturf et al. (2014) propose the iterative procedure solving timetable adaption and rolling stock rescheduling, as well as adding passenger simulation model. This paper considers to provide sufficient seating capacity to avoid dissatisfaction of passengers. It limits infrastructure mangers to adapt stopping patterns of the trains. The passenger simulation model is based on the assumption that passengers know the modified timetable and choose the fastest route to the destinations. The number of papers focusing on this kind of distributed model is still quite few. Some references can be found from the combination of passenger model and timetable rescheduling process, or the combination of passenger model and rolling stock rescheduling process. For the combination of passenger and timetable rescheduling, Binder et al. (2016) uses Pareto frontier to explore the trade-offs of passenger satisfaction, operational costs and deviation of original timetable. Sels et al. (2012) propose one feedback loop between passenger flow allocation and timetabling. Dollevoet et al. (2012) allow passengers to change the route in railway disruptions with the combination of passenger flow allocation and delay management model. Van der Hurk (2015) consider passenger satisfaction in the process of timetable rescheduling and propose to offer passengers with personalized information on alternative routes in railway disruption management. These personalized information is based on the probability and uncertainty of boarding. While for the combination of passenger and rolling stock, Kroon et al. (2015) approach the problem from train operating company’s point of view, assuming that the adjusted timetable is given as input. This paper tries to adapt
the rolling stock capacity to solving possible detour routes of passenger flows. A two-stage feedback loop is applied, which is the combination of passenger simulation and MIP model solving rolling stock rescheduling. The iterative process continues until no further improvements.

As is reviewed above, there are some experiences combining passenger simulation and timetable rescheduling, as well as experiences combining passenger simulation and rolling stock rescheduling. If the methods adopt iterative process among passenger simulation, rolling stock rescheduling and timetable rescheduling, how the information iteration should be is still discussable.

3. Discussions of possible rescheduling processes within the distributed model

3.1. Two rescheduling processes

In general, infrastructure manager and railway operators have the same general objective of providing railway services to the passengers of a high quality level. Depending on who should define new services for passengers in case of railway disruptions, two possible communication procedures can be applied, as shown in Figure 1 and Figure 2.

In the first rescheduling process, infrastructure managers play the core role and gather the information from both passengers and train operators. The information interactions are made up from four steps. Initially, passenger behaviors are simulated in the specific disruption scenario and the corresponding simulation results are passed to infrastructure managers. Then, infrastructure managers ask train operators for the resource availability, including rolling stock and staff. Afterwards, train operators feed the operation limitations back to infrastructure managers by comparing the operation requirements and resources availability. Ultimately, infrastructure managers reschedule the timetable combining passenger behaviors and resource availability, and then transmit the timetable information to passengers.

In contrast, in the second rescheduling process, one closed information interaction works among passengers, train operators and infrastructure managers. Three steps can be separated in this process. At first, passengers have different priorities and behaviors (e.g. cancelling schedules directly, waiting for recovery or transferring to other trains) reacting to different disruption scenarios. Passenger behaviors in railway disruptions are simulated and the information is transmitted to train operators. Second, considering both passengers’ requirements and resource availability, train

![Figure 1. The first rescheduling process in railway disruptions](image)

...
operators design the adapted services (e.g. which trains should be mandatorily kept or which connections can be cancelled). Last but not least, train operators’ dispatching advices will be sent to infrastructure managers who are in charge of eliminating timetable conflicts. Infrastructure managers reschedule the timetable and then inform passengers about the rescheduled timetable. The new timetable may cause passengers’ new reactions and such dynamic passenger information links three stakeholders into a close loop which should be optimized iteratively.

![Diagram of rescheduling process in railway disruptions](image)

In the current research, Model 1 is mainly applied in the process of timetable rescheduling (on-line), including the scenarios of railway disturbance and disruption. While Model 2 is widely employed in the process of line planning and timetabling (off-line). For railway disturbance, there is usually small adjustment of initial train timetable and high requirement of rescheduling calculation time. Most passengers can keep their service offered by the initial train operating companies, so that Model 1 with less connection between passengers and train operators is more suitable. However, in the process of disruption management, there is a higher risk of cancelling trains, stops, changing routes, which means it is hard for passengers to keep their initial services from the same company. In this case, train operating companies may hope to increase passenger numbers choosing their services, so that the link between passengers and train operating companies become stronger. Then, the discussion of whether Model 1 or Model 2 is more suitable of handling railway disruptions becomes more important.

### 3.2. Pros and cons of the processes

Considering the commercial competition within diverse train operating companies in the coming future, it is reasonable to propose the assumption that passengers can with free of charge taking the alternative services offered by the same operating companies while with a pretty high cost taking services from other companies. From this point of view, the second rescheduling process has significant advantages than the first one. The superiority of the second process is that each train operating company can propose their preference of alternative train sets which can maximise passengers’ interests within each train operating companies. These alternative sets can propose the priority of train cancelling, train time, train order, train connection, train routing, etc., with the integration of passenger simulation in case of railway disruptions and the operation resources. This process makes train operating companies to proactively understand passenger information and provide services for passengers. In contrast, the first rescheduling process misses the link from passengers to infrastructure managers, precisely missing the information of how to translate
passengers’ behaviours into train operation preferences that can be used by infrastructure managers. What’s worse is that train operating companies can only offer the operation resources information to infrastructure managers, without any active choices considering passengers’ choices. This passive situation makes train operating companies can do nothing in the market competition. The pros and cons of these two rescheduling process is summarized in Table 1

Table 1. Discussion of pros and cons of the two rescheduling processes

<table>
<thead>
<tr>
<th></th>
<th>The first rescheduling process</th>
<th>The second rescheduling process</th>
</tr>
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<tbody>
<tr>
<td><strong>Pros</strong></td>
<td>Train operators only needs to offer information of resources availability.</td>
<td>Benefit for multi train operators, train operating companies can propose service intention to infrastructure managers.</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td>Train operators have no idea about passengers</td>
<td>The negotiation procedure is time-consuming</td>
</tr>
<tr>
<td><strong>Infrastructure managers</strong></td>
<td>Less negotiation between train operators and infrastructure managers; less time to get the rescheduled timetable</td>
<td>The algorithms to solve the holistic problem should be clear.</td>
</tr>
<tr>
<td><strong>Pros</strong></td>
<td>Smaller alternative sets</td>
<td>Higher risk of no solution of conflict feasibility</td>
</tr>
<tr>
<td><strong>Cons</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Conclusions

In order to balance the trade-offs of objectives for passengers, train operators and infrastructure managers in railway disruptions, this paper reviews the related papers and summarizes that there are two main methods to solve these problem: the one is to establish the integrated MIP model for passengers, train operators and infrastructure managers, the other is the distributed model with the iterative integration between passenger simulation and either timetable rescheduling or rolling stock rescheduling. Since there are not so many papers dealing with the interactions among the three stakeholders (i.e. passengers, train operators and infrastructure managers), this paper discusses two possible rescheduling process with the difference of who makes the definition of passenger services. The pros and cons of each process are also listed for a convenience of comparison. In order to obtain a rescheduled timetable in a short time, the first process that infrastructure managers make definition for passenger services is more acceptable. In order to enhance the market competition of different train operating companies, the second process that train operators make definition for passenger services is more meaningful. For further research, the division of each holistic process needs to be explored more in detail, for example, the inputs, outputs and information interactions between every two stakeholders need detailed demonstration. This work is helpful for further study about the iterative optimization of railway disruption management.

Acknowledgements

This work is partially supported by China Scholarship Council.

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