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Modeling capacity consumption considering disruption program characteristics and the transition phase to steady operations during disruptions

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ABSTRACT

In passenger railway transport, acceptable operational quality levels and transparent passenger information are necessary – especially during larger infrastructural disruptions. One approach to achieve this objective are disruption programs (DRPs). Disruption programs are sets of pre-defined dispatching measures in case of certain (infrastructural) disruptions with the goal of ensuring stable operations during a disrupted situation. They are planned and negotiated in advance. Since they are already prepared, they are faster to implement and easier to communicate than ad-hoc dispatching measures. The operational quality of a DRP depends strongly on the development of the transition phase. In this context, the transition phase describes the process of stabilizing the operations of a railway network from the beginning of the disruption until steady operations during a disruption as foreseen in the DRP.

The described research proposes a method of determining additional parameters which allow modeling the capacity consumption of DRP turning stations during the transition phase. The proposed method helps to estimate the feasibility of a DRP in advance. This leads to DRPs with better operational results and thus to better acceptance and a wider implementation of the concept.

1. Introduction

1.1. Disruption programs (DRPs)

Disruption programs are a set of pre-defined dispatching measures in case of certain (infrastructural) disruptions with the goal of ensuring stable operations during a disrupted situation. These measures consist primarily of turnings on both sides of the disruption area and the reduction of the number of trains circulating in the network by cancelling single trains or whole lines. These measures are planned, negotiated and communicated in advance and include prepared instructions for dispatchers, operating and service personnel as well as passenger information (see Chu et al. 2012).

As they are designed in advance, the advantages of DRPs are shorter reaction times and faster and more precise communication with all parties involved. Since they do not have to create the basic solution ad-hoc and as they have to deal with fewer inquiries of operational personnel, dispatchers have more free capacities to focus on their main task – dispatching trains and taking crucial decisions.

With these mentioned characteristics, disruption programs represent a complementary approach to real-time traffic management and dispatching support tools like the current works of Corman et al. (2011), Törnquist Krasemann (2012) and Oetting et al. (2013). For an overview of the current works on real-time traffic management, see also (Tormo et al., 2013). The approach of disruption programs is complementary, since a feasible solution is already sketched out in advance and has not to be developed at the moment of the disruption. Although the DRP-solution might not be holistically optimal for the specific situation itself, passenger information can be carried out more effectively, if the solution is already known in advance – in contrary to real-time traffic management solutions which compromise the dispatcher's ability to inform passengers in advance.

At the moment, disruption programs are usually employed in Germany in urban railway net works (so-called "S-Bahn") with homogeneous traffic at short intervals. The concept or varieties of it are known and practiced internationally, too. Examples are the Swiss disruption management concept for railway operations (Fischer 2009), emergency scenarios in Denmark (Jespersen-Groth et al. 2009) and turning patterns in Japan (Nakamura et al., 2011).

The application of a DRP after disturbances evolves in different phases (see Fig. 1): After a disruption occurs, dispatchers and operating personnel need a certain amount of time to investigate the situation and assess the remaining resources in order to decide

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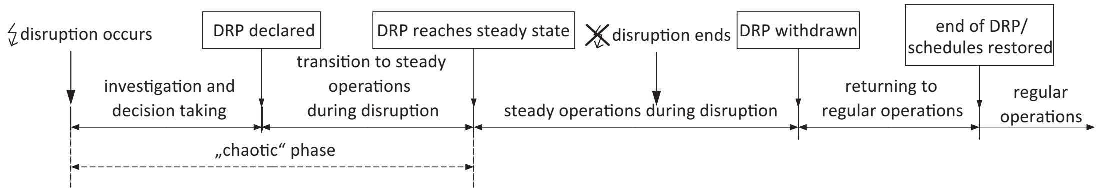

Fig. 1. Phases of the application of a disruption program.

on appropriate measures. After this investigation and decision making time, a DRP is declared and the transition to the phase of steady operations of a DRP begins. The DRP has reached a steady state when the trains are on their pre-defined (shortened) paths and the pre-defined (reduced) number of trains is steadily circulating in the system. Later, after the cause for the disruption has been cleared and certain prerequisites are given, the DRP is withdrawn and the returning to regular operations begins.

1.2. Implementation problems of disruption programs

Even though the concept of DRP is accepted and its effectiveness is proven, broad theoretical knowledge on processes and the transition phase to steady operations during disruptions is missing (Corman et al. (2011).

The authors' interviews with dispatchers and DRP-designers from the German rail operator Deutsche Bahn Regio (DB Regio) showed that the transition phase is not always functioning as planned and that even the expert practitioners were not always able to point out, what went wrong and why. Apart from the authors' work the special characteristics of implementing dispatching measures in railway operations have not been mentioned in the scientific literature so far. Also, the above cited works on real-time traffic management give neither answers on how to model the processes actually happening during the implementation of dispatching decisions, nor further reference to the transition phase.

With the aim of identifying the main influences on the transition phase of a DRP, a theoretical analysis and a case study on operational data of two big German urban railway networks with DRPs have been conducted (Oetting and Chu, 2013). The case study pointed out that one of the three main reasons for delays during the transition phase and during the entire DRP was queuing of trains at and in front of stations. Furthermore, a large proportion of delays occurred at turning stations in front of the disruption as well as in the end of the networks far away from the disruptions.

1.3. Altered capacity consumption during the investigation and transition phase

If one considers the available dispatching measures for DRPs, it becomes apparent that – additionally to communication flow problems – the main reasons for delays during the transition phase are capacity issues. Specifically, these are due to the following reasons which arise directly from the nature of DRPs and the "chaotic" phase (investigation and transition phase) itself:

1. After a disturbance occurs, a certain amount of investigation and decision taking time passes before a DRP is applied. Furthermore, some measures can only be applied train by train – for example giving special written orders to train drivers in a defined area. These additional time slots, where some trains just wait, influence their blocking time and have therefore to be considered when calculating the capacity consumption of DRPs.
2. The main dispatching measures of DRPs are turnarounds of trains at other stations than at their scheduled terminal stops. Furthermore, different platform tracks are often used for DRP turnings than during regular pass-throughs at these stations, which may cause more conflicts within these stations. Thus, the trains block these station sections much longer during DRP application as they turn around where they normally just stop and pass through. Therefore DRP specific turning supplements have to be considered when calculating the capacity consumption of DRPs.
3. Another DRP element is the reduction of the number of trains circulating in the network. The implementation of this reduction is not effected immediately, which leads to the situation, that the number of trains is not yet fully reduced during the transition phase. These remaining trains consume additional capacity during the transition phase and influence the normally fixed sequence and number of arriving trains at a DRP turning station.

Thus, the capacity consumption in turning stations during the investigation and the transition phase is higher than during a steady DRP. This may lead to congestion while the DRP itself is functioning well during its steady state. Therefore it has to be estimated in advance if the transition phase can function at all and if it will offer satisfactory quality.

1.4. Aim and structure of the paper

The presented research paper is an updated and extended version of Chu and Oetting (2013). It aims to investigate why the capacity consumption in DRP turning stations is higher during the transition phase than during steady state. Furthermore, additional parameters for the capacity calculation are introduced and a method to determine these parameters is described. By taking into account these parameters, a more realistic calculation of capacity consumption at DRP turning stations is possible. Basis for this method are the consideration of additional blocking time elements and the altered number of trains due to the operational specifics of disruption programs. Thus, the proposed method helps to design better functioning DRPs and contributes to the dissemination of the concept.

Before the developed method is described, the bases and existing approaches for the calculation of capacity consumption are briefly recapitulated in section two. In section three, it is described why additional blocking time elements have to be taken into account during a disruption and how to estimate their lengths. Furthermore, a heuristic for modeling the reduction of the number of trains during the transition phase is described. To support the statements in section three, values from the analysis of operational data of two large German S-Bahn networks are presented. Based on these findings, the general method of determining the parameters for calculating the capacity consumption at turning stations is described in section four. The presented method for modeling the DRP characteristics is independent from the capacity calculation method employed (constructive, analytical or simulation). Despite, using the occupancy rate in order to state the feasibility of