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DISRUPTION PROGRAMS IN PASSENGER RAIL TRANSPORT – ENSURING STEADY OPERATIONS DURING DISRUPTIONS

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This is an abridged version of the paper presented at the conference. The full version is being submitted elsewhere. Details on the full paper can be obtained from the author.

ISBN: 978-85-285-0232-9

13th World Conference on Transport Research

www.wctr2013rio.com

15-18 JULY 2013
Rio de Janeiro, Brazil

DISRUPTION PROGRAMS IN PASSENGER RAIL TRANSPORT – ENSURING STEADY OPERATIONS DURING DISRUPTIONS[1]

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ABSTRACT

In rail transport, acceptable operational levels and transparent passenger information are necessary – even during larger infrastructural disruptions. One possibility to achieve this objective are disruption programs (DRPs) which are planned and negotiated in advance and which are therefore faster to implement and easier to communicate. However, it is still not fully understood how to implement disruption programs quickly and reliably during a disruption.
The paper reports on suitable procedures to achieve this steady state more quickly. This helps operators to manage disturbances faster and improves operational quality. In order to quantify the identified factors influencing the time until the steady state is attained, real-life operational data of disturbance programs is analyzed. Disturbance programs are usually developed for each network individually and are based on expert experience. With empirical findings of the presented field of research and derived common rules supporting the expert knowledge, disruption programs complement real-time dispatching software for operators.

Keywords: disruption programs, disturbance management, operations passenger rail transport, operational quality, disruptions

1 INTRODUCTION

Increasing operational quality in railway systems

During the last years, demand for passenger and freight railway transportation increased considerably [RADTKE, 2011]. This increases network capacity consumption and leads to decreased punctuality in operations. Additionally, customers expect higher levels of operational quality in terms of punctuality. This implies railway infrastructure and train operating companies have to turn their attention towards improving operational quality on all levels. One part is the operational handling of disruptions as they cannot be influenced or eliminated in a domain as complex as railway operations.

[1] Abstract has been submitted under the title „Towards Steady Operations during Disrupted Situations in Passenger Rail Transport".

Strategies of dealing with disruptions in railway operations

When dealing with disruptions during operations the overall objective is minimizing delays and ensuring the availability of residual capacity during the disruption. With reference to [MIEDE, 2010], the countermeasures for dealing with disruptions in railway operations can be categorized into:

1. detecting occupation conflicts before they happen (and solving them)
2. mitigating and recovering from the consequences of delays that already happened
3. preventing the reproduction of events leading to delays

These three strategies complement each other and have to be regarded holistically. As of today, practitioners and researchers pursue diverse approaches to implement these strategies. The authors conducted interviews with dispatchers from the German rail operator Deutsche Bahn Regio (DB Regio). These interviews showed that the dispatchers mostly rely on their experience when it comes to detecting potential occupation conflicts and mitigating the consequences of already occurred delays. The interviews also indicated that only few common guidelines and dispatching rules for disrupted situations are available.

However, if the dispatching quality depends predominantly on the dispatcher's experience and fitness, consistent and high dispatching quality is not guaranteed. To mend this weakness, state of the art research aims to develop dispatching algorithms with the goal of developing dispatching (support) software. These approaches feature the detection of potential occupation conflicts and solving algorithms (e. g. [DAAMEN, 2009] and [PANKE, 2012]) as well as simulations and dispatching algorithms to recover from disturbances in simple [JESPERSEN, 2009] and more complex networks [CORMAN, 2011]. These approaches do not support actual prevention, as they are based on real time and on ongoing assessment of the actual situation.

Preventing the reproduction of events leading to delays can be carried out by a lot of different approaches. On one hand actions can be taken to prevent disturbances from happening. This approach is important but not sufficient in a system which is as dependent from many different internal and external influencing factors as railway operations. On the other hand prevention means preparing guidelines and ready-to-use measure bundles. They support and enhance dispatching and communication in case of disruptions and help to contain further delays. One effective way of prevention is the application of disruption programs (DRPs) which are described in the next section in more detail.

Disruption programs (DRPs)

Disruption programs are a set of pre-defined dispatching measures in case of certain (infrastructural) disruptions (see figure 1) with the goal of ensuring stable operations during a disrupted situation. They are planned, negotiated and communicated in advance and include prepared instructions for dispatchers, operating and service personnel as well as passenger information [CHU, 2012].

As they are designed in advance, the advantages of DRPs are shorter reaction times (since the solution is already sketched out) 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.

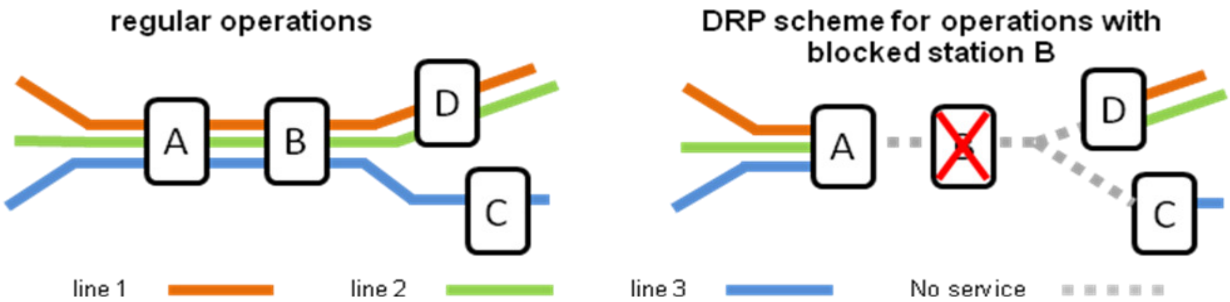

Figure 1 – operational scheme for a working infrastructure and a DRP

Transitioning to the steady operation of a DRP

The application of a DRP after a disturbance has occurred is put into effect in different phases (see figure 2). 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 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 starts. 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, when the reason for the disruption is removed and certain prerequisites are given, the DRP is withdrawn and the returning to regular operations begins.

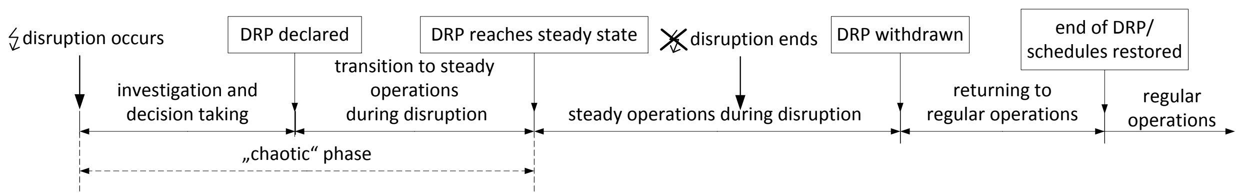

Figure 2 – phases of the application of a DRP

The progression of the transition phase towards the steady operation of a DRP is crucial to its effectiveness and efficiency. The sooner the DRP runs stable the better the operational quality of the specific application of the DRP.

Aim and structure of the presented research paper

Today, DRPs are implemented successfully in several German urban railway networks (so-called “S-Bahn”) and the effectiveness of the concept has been proven in practice. The concept or varieties of it are known and practiced internationally, too. Examples are the Swiss disruption management concept for railway operations, emergency scenarios in Denmark [JESPERSEN, 2009] and turning patterns in Japan [Nakamura, 2011]. However, it is still not fully understood how to implement disruption programs quickly and reliably during a disruption. Therefore, a systematic analysis of influences on DRPs with a focus on the transition phase, the description of the cause-effect relationships as well as a standard process for DRP application is missing.

The work at hand aims to identify and quantify the influences on the transition to steady operations in order to develop suitable directives and procedures to achieve a short transition phase. Thus the work contributes to the strategies of mitigating and preventing delays which are mentioned in the section above.

In order to identify the influences on the transition to steady operations a systematic analysis of DRP dispatching measures is conducted. The results are described in section two. Section three addresses the analysis of real-life operational data from two German urban railway networks which has been conducted to complement the list of influencing factors and to quantify them. Based on the findings of the previous sections, suitable advice and procedures to achieve a short transition phase are developed in section four. The drawn conclusions and the prospects for future work are given in the last section.

2 FUNDAMENTAL INFLUENCES ON THE DRP TRANSITION PHASE

Categorization of the different influences on the DRP transition phase

Railway operations in general are influenced by a large and different number of factors. These are usually sorted into the categories of resources (vehicles, personnel, infrastructure), and internal (e.g. operational procedures) and external influences (e.g. external disturbance causes; other operational companies). The factors of these categories have been analyzed with regard to the transition phase of a DRP and complemented with additional DRP relevant factors. They are listed in table I, where it is also indicated if there are possibilities to mitigate the negative influences.

Depending on location, type and time of the disruption the transition phase is negatively influenced in different ways. If a disruption occurs at important nodes in the network the impact of the disruption is more likely to spread since a lot of trains can be affected by it. The location of the disruption in relation to the entire network affects the dispatcher's workload and thus has an impact on the development of the transition phase, too. If the disruption is located in the middle of the network, for example, some lines have to be turned at both ends of the disruption. Therefore the train can continue under the original number at one side whilst another train number has to be generated for the substitute train at the other side. These additional dispatching tasks occupy the dispatcher additionally. Furthermore, the number of trains running in the network – depending on network size and the time of peak hours – influences the number of necessary dispatching steps directly and thus the dispatcher's workload. Predictable or scheduled events such as construction works, defusing of unexploded WWII-bombs or mass events usually lead to a reduced chaotic phase (see figure 2) as the investigation and decision finding process takes place before the disruption happens. The nature of the disruption can be differentiated between an emergency stop where driving orders are withdrawn, the controlled halt of operations ("Drive into the next station and wait for further orders.") and the declaration and application of the DRP without pausing operations in certain areas at all. If trains have to be stopped in order to protect them or until a solution is found, the dispatcher's workload automatically increases as (re-) driving orders have to be given to each train driver individually. To summarize, all additional tasks increase the dispatching workload and reduce the available time for coordination and solution finding.

Table I – systematic compilation of influences on the transition phase with an indication of possible leverage

Categories and characteristics		Positively influenceable by dispatcher/transport company?
External factors	**Type of disruption and impact**	
	Location of disruption within the whole network	No
	Location of disruption within the DRP area	No
	Nature and predictability of disruption	No
	Number of trains in the network at the time of disruption	No
Internal factors	**Communication and decision processes**	
	Number of parties involved	No
	Completeness and reliability of information on disruption	Partially positively influenceable by well trained personnel but always depending on type of disruption, too.
	Time until information on disruption is available	No, depends on nature and gravity of the disruption
	Length of decision process	Yes, in function of existing processes.
	Time until DRP information reaches the customers.	Yes, in cooperation with train station operators
	Comprehensibility of DRP information for internals AND externals.	Yes
	Number of transactions in IT systems	Yes, but only in long term by implementing new business processes and software
	Effectiveness of dispatching measures	Yes (see also table II)
Resources	**Personnel**	
	Workload and additional tasks for the dispatchers	Yes, but only with additional resources.
	Availability of additional driving personnel	Yes, but only with additional resources.
	Training for DRP appliance	Yes, but only with additional resources.
	Discipline and compliance at DRP application	Yes, but only in a long term process
	Vehicles	
	Availability of additional vehicles	Yes, but only with additional resources
	Versatile usability of available vehicles	Yes
	Infrastructure for deviating, turning and siding	
	Availability and accessibility of infrastructure	Yes, but possibly only with additional resources
	Available capacity	No
	Capacity consumption	Yes, e.g. by the dispatching sequence

The correct selection and configuration of the employed dispatching measures do also influence the effectiveness of the DRP and thus the quality and length of the transition phase. The particular effects are described in the following subsection.

Quality and length of the transition phase depend directly on the communication quality and the length of the decision finding process: The involvement of different transport companies in the discussions with the railway infrastructure company may prolong the coordination process. Also incomplete and/or unreliable information may influence the length of the decision finding process and may lead to inappropriate solutions which worsen the operational situation instead of improving it. The longer the solution finding process takes, the more trains might queue up in front of the disruption, complicate the dispatching scenario and influence the length of the transition phase negatively. Additionally the quality of communication, like the comprehensibility of the DRP content for internal and external personnel and for passengers as well as the duration until the DRP information has reached the passengers, is important for a short and smooth transition phase.

Concerning resources like personnel, vehicles and infrastructure, many different factors influence the success of the transition phase. For driving personnel and vehicles the beneficial factor of having additional resources in case of a disruption is obvious as it ensures more flexibility in dispatching. This is equally valid for infrastructure since additional routes, deviations and siding possibilities with sufficient capacity increase flexibility in dispatching during the disrupted situation. Furthermore, all personnel involved have to be well trained in the DRP application process and a process-related discipline has to be enforced. Additionally, enough dispatching personnel has to be guaranteed so that there is an actual chance to perform all necessary tasks.

As indicated in the second column of table I, not all categories of influences can be positively influenced by good preparation and DRP planning. Type and time of the disruption cannot be influenced, for example. The quality of the communication process can be improved by introducing communication standards. Improvements regarding acceptance and mastery of the DRP concept as well as discipline enforcement can be achieved by intensive training of personnel in combination with change management. Additional resources regarding dispatching and driving personnel, vehicles and infrastructure are helpful during a disrupted situation but are often not available due to lean/optimized operational concepts which cut as much reserves as possible. So, influencing the already mentioned categories positively is either a really long process or not quite tangible.

For this reason, the chosen dispatching measures are the focus of the remaining research. If the influences and implications of a chosen dispatching measure in a DRP are fully understood, additional measures can be provided to mitigate possible side effects on the transition phase.

Dispatching measures and their (implicit) effects

Based on a previously developed list of possible dispatching measures [CHUFORNAUF, 2011] all DRP relevant dispatching measures are identified. Dispatching measures in the context of DRP usually target on turning trains in front of the disrupted area, deviating trains around the disrupted area and reducing the number of trains circulating in the network in order to control operations more easily. But at a closer look at the dispatching measures shows the following: The relieving effect in the target area leads to negative and sometimes congesting effects elsewhere at the same time. This may influence, again, the transition phase. In table II all available dispatching measures and their explicit and implicit effects on the network are listed.

Table II –DRP dispatching measures and explicit/implicit effects on the railway network

<table>
<tr><th rowspan="2">Dispatching measures</th><th colspan="2">Intended effects explicitly relieving the infrastructure</th><th colspan="2">Possible effects implicitly stressing the infrastructure</th></tr>
<tr><th>Releasing of declared train paths</th><th>Shorter occupation times in existing train paths</th><th>Usage of additional train paths</th><th>Longer occupation times in existing train paths</th></tr>
<tr><td>Deviation (different route)</td><td>X</td><td></td><td>X (on deviation route)</td><td>X (if deviation route is already heavily used, trains wait in original tracks for the deviation)</td></tr>
<tr><td>Deviation within stations (stops stay as planned)</td><td></td><td>(X)</td><td></td><td>X (if deviation path interferes with those of other trains, e.g.by crossing the main track)</td></tr>
<tr><td>Line cancellation (all trains of a line are cancelled)</td><td>X</td><td></td><td>(X) (trains going in/waiting for siding)</td><td>X (higher passenger volumes in other trains may lead to longer dwell times)</td></tr>
<tr><td>Line shortening(trains are not running until their final destination</td><td rowspan="2">X (in parts where run is cancelled)</td><td></td><td></td><td>X in turning station</td></tr>
<tr><td>Line breaking (Line is cut in the middle; some stations are not served)</td><td></td><td></td><td>X in turning station</td></tr>
<tr><td>Cancellation of certain stops</td><td></td><td>X (train is passing instead of stopping)</td><td></td><td>X (higher passenger volumes in other stations may lead to longer dwelling times in other stations)</td></tr>
<tr><td>Additional stops</td><td></td><td></td><td></td><td>X (stations where train is stopping instead of passing)</td></tr>
<tr><td>Capacity adjustments (reducing running intervals)</td><td rowspan="3">X (on whole route)</td><td></td><td rowspan="3">(X) (trains going in/waiting for siding)</td><td></td></tr>
<tr><td>Cancellation of certain trains</td><td></td><td rowspan="2">X (higher passenger volumes in other trains may lead to longer dwell times)</td></tr>
<tr><td>Temporal shift of train (delayed train runs under the number of the next run on same route)</td><td></td></tr>
<tr><td>Partly cancellation of trains</td><td>X (in parts where run is cancelled)</td><td></td><td></td><td>X in turning station</td></tr>
<tr><td>Coupling trains</td><td>X (on joint route)</td><td></td><td></td><td>X(because of the coupling in the station; longer train)</td></tr>
</table>

Implications for the data analysis

These in table II described implicit negative effects of DRP measures on the transition phase have not been considered in research and rarely in operations until now. The interviews with dispatching experts and DRP developers from German rail transportation company DB Regio confirmed that only the stable functioning DRPs (where trains circulate already on the pre-defined routes and with the reduced number of trains in the network) form the basis for plausibility and feasibility tests. The general assumption is that, for example, trains will be reduced as planned and that there will be no complications. The following analysis shall give answers on the reasons for delays at the beginning and during the application of DRPs and indicate whether there is a connection between the dispatching measures and the postulated implicit effects.

3 ANALYSIS OF DELAYING INFLUENCES DURING THE TRANSITION PHASE

Analysis goal and available data

The goal of the analysis is to identify reasons why operations in the transition phase run with difficulties. Thus it is analyzed where delays occur, why they occur and how they affect the punctuality of the entire system.

Therefore, operational data of two big German urban railway networks was analyzed. Both networks are monocentric where most or all of the lines share a stretch of track (the so-called "Stammstrecke"; trunk line). These trunk lines form the bottlenecks of the systems as the entire network is subject to delays if there is a disruption in this section. For these networks, DRPs have been implemented since about five or ten years respectively in the case of disruptions in the trunk lines. In the first system about 750 and in the second system about 1200 trains are running daily through the respective trunk line. The operational data for both networks dates from 2012 when DRPs have been applied in the course of disruptions. Overall, four DRP applications have been analyzed (two for each system).

The available data are records of train movements within the infrastructure which are collected by the infrastructure operator and operational data of the train operator regarding punctuality and passenger information. The data from the infrastructure operator contains records about scheduled and actual arriving times and tracks at each station for each train number. The data from the train operator contains punctuality values and digitally available passenger information for the considered days. Information about specific dispatching decisions during these disruptions is not available as interviews with dispatchers on duty have not been conducted. Out of this data, the local punctuality and the development of punctuality of trains, track occupation and some passenger information can be retraced.

Analysis approach for the case study

The analysis focuses on three main points. The first question is why and where delays occur after the declaration of a DRP. Therefore all trains which were running at the time of declaration of the DRP and all trains which started after the declaration are investigated. Out of these trains, for those which get delayed for more than five minutes during their run the location, the reason and the type of delay (gradually or jumping, see sections below) are registered. From these results general conclusions are drawn concerning delay reasons and vulnerable locations during DRPs.

The second question focuses on starting delays – therefore, out of all trains which started after the DRP declaration those which started already delayed are of interest. Here it is analyzed what the common reasons for a delayed start were as well as if there is a correlation between the location of the starting station within the network and the delayed start. From these results conclusions for general reasons for starting delays and for characteristically locations for these delays are drawn.

The third focus is placed on trying to quantify how well a DRP was actually carried out. Next to taking the number of cancelled trains and the sum over all delays related to the disruption, another approach is taken. The trains are categorized by their location at the time of DRP declaration and to investigate how well trains of each category were managed.

Analysis of delayed trains

Gradual delays and delay jumps

For all trains which got delayed for more than five minutes during their run the type of delay (gradually or jumping) is registered. Here, both types of trains are considered: those which are already running at the time of DRP declaration and those which are starting after DRP declaration (regardless whether delayed or punctual). Gradually delayed trains are defined as trains which get delayed for a maximum of two minutes between two stations or checkpoints. The reasons for these delay progressions are not recorded by the system. Furthermore measuring errors are possible. For this reason, the delay progressions with a maximum of two minutes per step are not analyzed further, as it is not possible to determine the exact reason for this delay by the available data. All delay progressions over two minutes between checkpoints are considered as delay jumps. For all these jumps the location and time are recorded and the reason will be identified.

Case study German urban railway networks – reasons and locations for delays

For the case study four main reasons for delays during the train run could be identified (see figure 3): queuing of trains due to congestion, gradual delays, deviations, and other reasons.

The reason congestion includes all cases with delay jumps where a train is waiting in a block until the adjacent block (usually a station) is free to enter. The reason deviation includes all cases with delay jumps which are induced by the dispatching measure deviation. For example, this comprises the waiting time until the deviation track is available, additional prolongation of driving time or additional turning time if the deviation happens to pass through a dead-end train station. Deviations are only employed in system 1. The delay reason of congestion is connected to possible capacity problems during the DRP declaration and application. This becomes evident from the available train movement data as trains are queued up each in one block after another. The delay reason deviation is partly connected with capacity problems which can occur on deviation tracks and on their entrances too.

The reasons for gradual delays and other indicate a non negligible number of delays which unfortunately cannot be analyzed satisfyingly with the available data. In system 1 they represent 50 % and in system 2 they represent 55% of all identified causes. The reasons for "other" may include missing driving personnel, a (too long) duration until dispatching decisions are made, high dwelling times due to high passenger volumes and further reasons. To clearly identify the correct reasons, comprehensive data of all communications, personnel and vehicle dispatching decisions etc. would be needed. It is important to concentrate further research on defining these two groups of reasons more precisely in order to gain more insight on possible remedies.

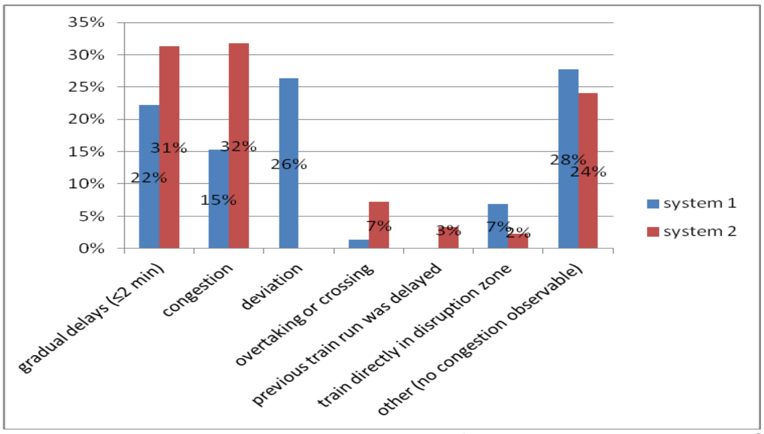

Figure 3 – ratio of delay reasons per system (accumulated values for both DRP per system), [S1, D1 = system 1, DRP 1]

With the goal to indicate whether the delay reasons congestion and deviation relate to specific locations, the locations of occurrence have been recorded and classified. The results which are displayed in figure 4 indicate that most of the delays due to congestion and deviation occur in the trunk line. As DRPs are mostly developed for disruptions in the area of the trunk line, most of the trains are deviated around respectively turned in that area. Therefore the trunk line is prone to congestion to a certain extend.

Furthermore it is assumed that the considerably high amount of congestion cases in system 2 (see figure 3) can be attributed to the overall higher number of trains in system 2. When there are a lot of trains in the network at the time of DRP declaration, it may lead to waves of trains queuing up in front of the disruption because turning capacity in the station and dispatching capacity in the control center are too low. Thus dispatchers cannot handle all trains in time and the situation aggravates.

More specific conclusions on the type of location where congestion occur cannot be made at that point.

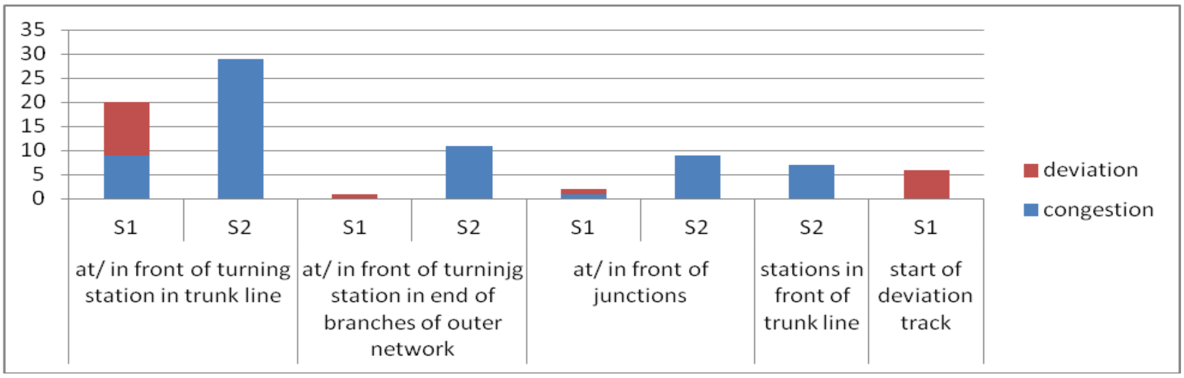

Figure 4 – type of location where delays occur due to congestion and deviation, [S1, D1 = system 1, DRP 1]

Analysis of starting delays for trains starting after DRP declaration

In the second step, all trains which start their run after the DRP-declaration are considered. Here, the analysis focuses on trains which start already delayed (see figure 5).

For all trains which begin their run with a delay, the reason and the starting station are recorded. Figure 6 indicates clearly that the delay of previous trains is the main reason for delayed starts. Thus the delay is propagated to the consecutive trains. The propagation does not only occur specifically at the DRP stations but also at regular turning stations at the end of the branches of the outer network as it is shown in figure 7.

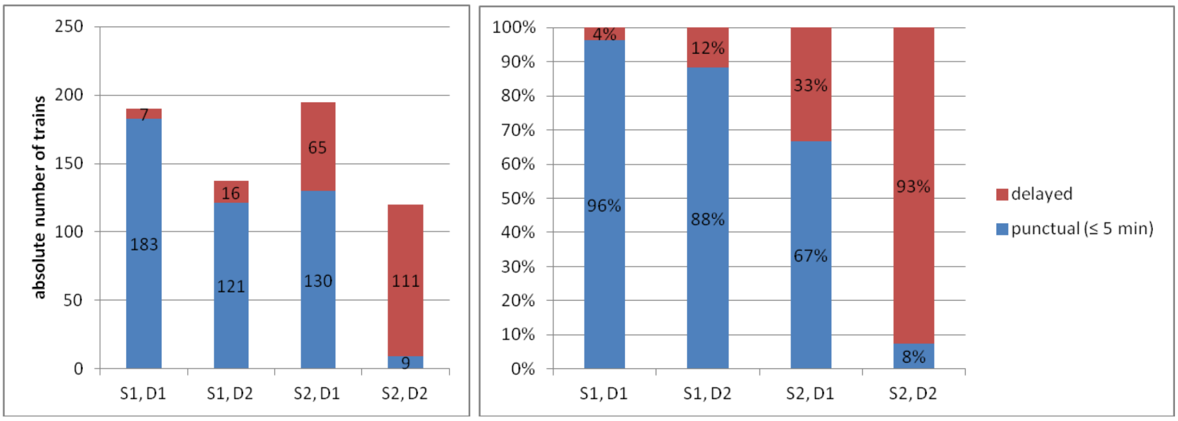

Figure 5 – trains beginning after DRP declaration (by absolute numbers and percentage), [S1, D1 = system 1, DRP 1]

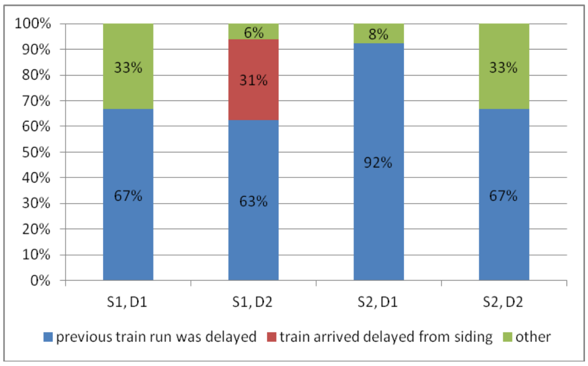

Figure 6 – reasons for trains beginning delayed

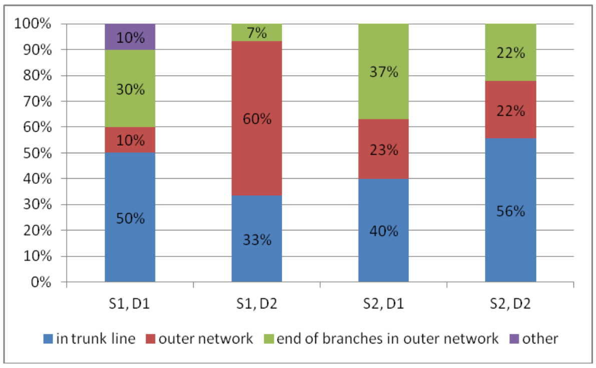

Figure 7 – location of stations where trains begin delayed

[S1, D1 = system 1, DRP 1]

Figure 5 depicts another significant difference between the two systems: In system 1 a high proportion of trains which start after the DRP declaration begin on time, while a lot of trains in system 2 start their runs delayed. A reason for this divergence is seen in the different departure regulations in the two systems. In system 1 every (DRP-) turning station has an additional DRP schedule for the starting times of the next run. For a better understanding, the following example: At a DRP turning station, departures of the new runs are scheduled for 07:15 and 07:30. If the train that should have started at 07:00 is ready at 07:08, the run which was supposed to start at minute 07:00 is cancelled and the train only starts at minute 07:15.

DRP-departure rules in system 2 are less specific. There, the only rule is that a train will turn to the next suitable run. To stay with the previous example – in system 2 a train would start 8 minutes delayed. As one can see, the departure rules in system 1 ensure that most of the delays are not propagated to the next train run. The subsequent consequences and advantages or disadvantages of such a rule are discussed in section 4.

Analysis of improvement potential of the transition phase

Defining train categories by position and maximum delay

In order to measure the dispatching success during the transition phase, the analysis focuses on different groups of trains which are defined by their location in the network at the time of DRP declaration (see also figure 8). Depending on their location in relation to the disruption at the time of DRP declaration the trains can either be salvaged or not.

<u>Green trains</u> run towards the disruption, but are in front of the DRP- turning or -deviation point or move away from the disruption. Green trains can theoretically still be directed away from the disruption and thus salvaged and should be punctual.

<u>Yellow trains</u> run towards the disruption and have already passed the DRP- turning or -deviation point, but did not reach the last technical possible turning point in front of the disruption, yet. Yellow trains do not automatically fit into the DRP, but there is a possibility to prevent them from entering the adjacent blocks of the disruption.

<u>Red trains</u> have reached the last technical possible turning point in front of the disruption or have already passed it and are directly at the disruption. Red trains are either the cause of the disruption or in adjacent blocks of it and will be delayed in every case.

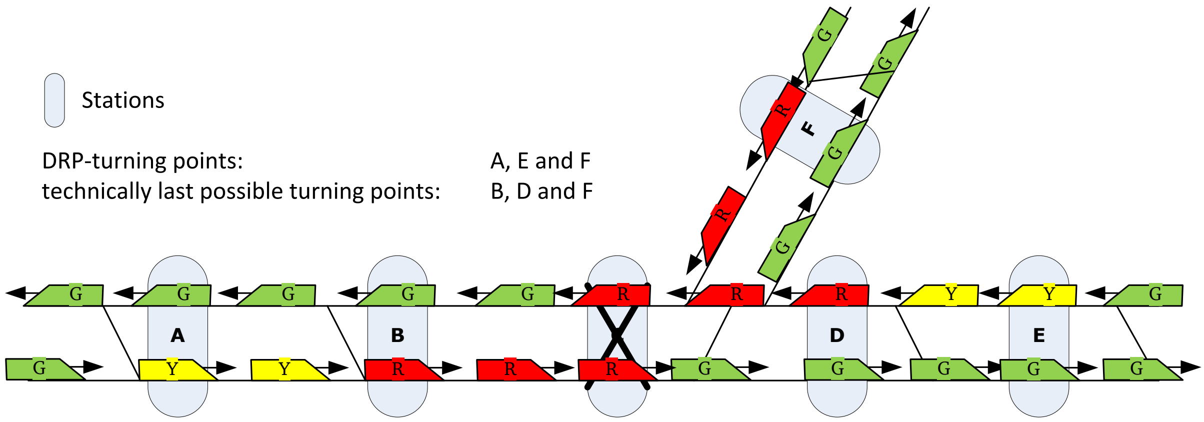

Figure 8 – categorizing trains by their position at the time of DRP declaration (general example)

Table III – categorization of trains by position and maximum delay for assessing the improvement potential

trains categorized by position in the network at DRP declaration	**trains categorized by maximum delay during run**	
	max delay < 6 min (punctual)	**max delay ≥ 6 min (delayed)**
Green	theoretically manageable and practically punctual	theoretically manageable but practically delayed
Yellow	theoretically at risk, but practically punctual	theoretically at risk and practically delayed
Red	theoretically delayed, but practically punctual	theoretically and practically delayed

trains in these categories will be analyzed further

The categorization by location at the time of DRP declaration provides information about the prospects of each train being delayed by the disruption or not. This is compared to the maximum delay of the train during its run (see also table III). The maximum delay has been chosen because focusing only on the departure or the arrival delay may result in inaccurate conclusions as a train can get delayed and catch up during the same run. According to the definition of Deutsche Bahn, trains are defined as punctual if their delay is less than six minutes.

By identifying the number of trains running in the network at the time of DRP declaration and by relating them to the number of potentially and actually 'saved' trains an assessment on the potential of improving the transition phase can be given.

Case study German urban railway networks – trains circulating at DRP declaration

In system 2 almost twice as many trains as in system 1 circulate in the network (see on the left side of figure 9). The number of trains in system 2 on the first day is representative for system 2. The number of trains in system 2, day 2 is diminished because of a disruption earlier that day.

A look on the ratios of train categories (see on the right side of figure 9) shows that in system 1 proportionally more trains can be found that are theoretically 'lost' and practically delayed. The difference between system 1 and system 2 is that in the first system three lines are ending regularly in the DRP area. Since their turning stations belong to the DRP area, a large number of trains has already passed their last turning opportunity and is in the disrupted area. This may almost certainly lead to difficulties during the transition phase. It is possible since clearing the trains out of the area could result in hindrances of the trains turning according to the DRP in front of the area. To that effect, more problems may arise than in system 2 due to 'red' trains.

Considering the relations of potentially manageable and actually delayed trains between both systems, no clear picture arises. It is to notice that potential for improvement exists since the amount of trains that were savable but actually delayed in average overpasses more than 20% in each case.

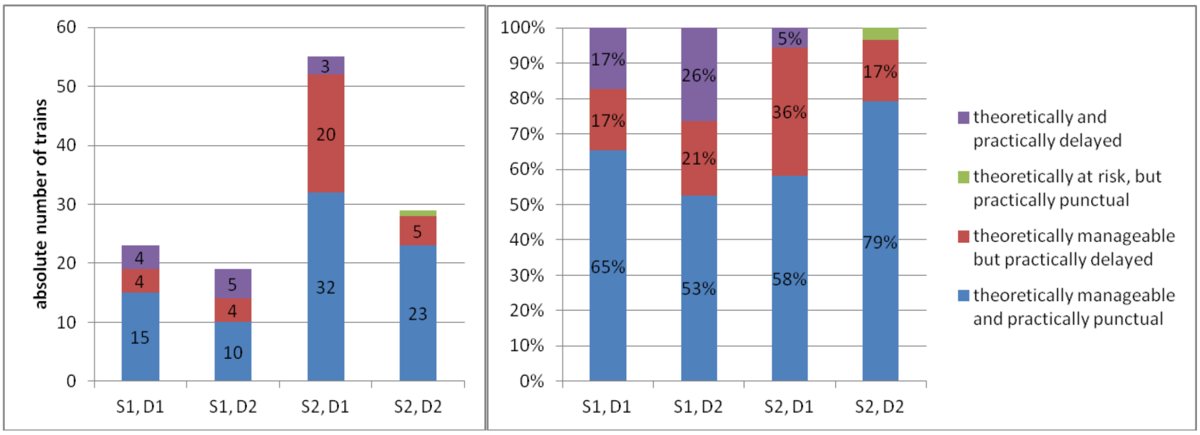

Figure 9 – case study results – classification of trains circulating at DRP declaration (by absolute numbers and percentage), [S1, D1 = System 1, DRP 1]

Discussion of results and conclusions from the case study

As described the beginning of this section, only two different DRP applications of two different German urban railway networks with two disruptions each have been analyzed for this case. This is due to the reason that a lot of train records had to be investigated individually. It is obvious that neither statistic significance is given nor all possible reasons for problems during the transition phase have been observed in the case study. But this is the first methodical case study on DRP which are implemented in real operations and the case study nonetheless points out several effects which have to be investigated further.

In section 2 different possible influences on the length of the transition phase have been explained. In the case study not all influences could be identified, but this is mostly due to the number of available cases. The following aspects were identified during the case study:

- With an average of 25% in both systems, operational problems without obvious link to infrastructure capacity problems are one of the main reasons for delays (category ‚other'). Another considerable number of delays are due to gradual delays which account for 29% in average. These results point out that further research on both categories is needed.

- It became apparent that delays occur which are obviously in connection with an altered use of capacity in turning stations during DRP transition. This effect is currently investigated [Chu, 2013].
- The propagation of delays onto following trains of the same or of different lines happens above all during turnings. Here, the propagation can be contained if specified departure times and turning rules in case of DRP application are used (see following section).
- The number of trains, which are theoretically and practically delayed, also depends on the regular layout of the lines: the more lines end regularly in the trunk line the more trains can be expected in the category of theoretically and practically delayed trains.

4 IMPROVING OPERATIONS IN THE TRANSITION PHASE

General goals for improvement

As described in table I and II, several aspects of a DRP can be influenced positively by good DRP planning and processes. The main goal is to accelerate all necessary processes by shortening the transition phase regarding faster decisions, faster actions, better communication flow and fewer questions from operational personnel. The second goal is to improve the process stability.

First, fast decisions are possible if directives and instructions on how to proceed are available and internalized by all personnel. This means that not only the DRPs have to be taught to the personnel, but the underlying principles have to be understood. Thereby consistent and effective decisions are possible. This area of improvement is mostly decided by so called soft factors like work discipline and training.

Second, DRP stability is achieved by improved DRP design. It is not only important that a DRP is feasible when being in the steady state but that it is possible to reach that steady state without major problems, respectively at all. This means that DRP planning has to cover the specific processes during the transition phase and to anticipate solutions for problems arising specifically out of the transition phase. Approaches for better DRP planning and application are described in the sub sections below.

Area of improvement 1 – Choice of turning stations

In general all the effects during transition phase have to be already anticipated during DRP design. This includes the following: There might be a larger number of trains as anticipated which queue up in front to the disruption. This is either the case when lines are ending regularly in the DRP area/trunk line and/or if there is a high frequency of trains. The queuing can be inherent to the DRP if the arrival rate at the DRP turning station is higher than the minimal turning time at DRP turning station. Then, the DRP has to be adjusted. The number of trains has to be split, e g. by lines) and an additional DRP turning station ahead has to be assigned.

The queuing can also occur if the arrival rate at the DRP turning station is lower than the minimal turning time at DRP turning station. Here, the queuing might be attributed to operational circumstances and is not DRP inherent. For these immediately affected trains it is advisable to let them turn before they reach their DRP turning station at the beginning of the transition phase in order to dissolve the queuing. In this manner, a major delay reason (waiting until turnings are finished) is reduced. The authors understand that the proposed procedure negatively influences the quality of passenger information in the beginning of the transition phase. However the trade-off between prolonging the dissolving of the queue and accelerating the transition phase is in favor of deviating from the DRP during the transition phase.

Area of improvement 2 – limiting delay propagation at turning stations

The case study from section 3 showed that defined starting times for DRP turning stations are an effective way in preventing delay propagation at turning stations as the system is regulating itself.

The inconveniences of this measure are the difficult application at stations where more than one line is turning and the application in larger networks with high train intervals. If more than one line is turning in a station and if only one track per direction is available, waiting for the next defined DRP departure for a train of line A might delay a succeeding train of line B, whose defined DRP departure is sooner. As a consequence, a separate track for each line turning in a station has to be allotted. If this requirement is not met, propagation happens and trains will start delayed.

Area of improvement 3 – operational procedures for the transition phase

DRP decision guidelines and operational procedures lead dispatchers and operational personnel during disrupted situations which are not exactly anticipated in the DRP. This is important since the possibilities for disruptions are highly diverse and existing DRPs will not always be completely suitable for the actual situation.

One recommendation is already described in the subsection of “area of improvement 1” – to decide to turn trains at a certain point in front of their designated DRP turning station in order to dissolve unanticipated queuing in front of them. Decision rules or guidelines are also necessary for the case that full and consistent information is not or will not be available in time. For example, there have to be guidelines after which time a DRP has to be applied. In this manner, an “it will soon be over (and will sort out by itself)”-attitude is prevented. Preventing this attitude is a crucial point as doing nothing is usually the least suitable measure during disruptions. Of course, the implicit costs of a DRP application have to be traded against the explicit costs of doing nothing, but the effects of a procrastinated DRP are much worse since the transition phase gets prolonged the more trains queue up uncontrolled during transition.

Another problem is locating available driving personnel for further dispatching: If all drivers report to the dispatcher those will be overloaded by the sheer amount of communication. On the other hand, the dispatcher needs to know who is available. Therefore it is advisable to implement reporting procedures for available train drivers in the DRP case.

Area of improvement 4 – communication processes during the disruption

Effective and efficient communication and coordination influence the transition phase positively. If the instructions are clear for everyone and if the solution outline is agreed upon fast, the solution finding and implementation phase is shorter. Thus, less trains queue up in front of the disruption and less additional dispatching activities are necessary.

DRP information that is standardized in form and content can enhance the communication process. It makes it easier to formulate messages that are understood by everyone involved and ensures that all necessary information is available. Furthermore a reporting process/chain of information ensures that everyone is kept in the informational loop.

In connection with the communication it is also advisable to develop IT support. At present, dispatching measures are entered for each train individually into the IT-Systems, in Germany. This proves to be a problem during disruptions since the impact of a disruption and the dispatcher's workload increase proportionally with the number of trains involved. As a consequence, it happens often that the dispatcher stays behind with entering his or her decisions into the dispatching systems. Here, batch processing and entering of train information for an entire disrupted area would speed up the process considerably.

5 CONCLUSION AND FUTURE WORK

Conclusion

The requirements for operational quality, including fewer delays at constant or rising capacity consumption, put high demands on railway and train operators. Especially the availability of residual capacity during disruptions and punctual and stable operations are important to train and railway operators and passengers as well. One possibility to meet these requirements is the application of disruption programs (DRPs). The DRP concept is internationally known and its efficiency is confirmed. Nonetheless, the knowledge about the transition phase from the chaotic disrupted situation to a stable disruption exists only insufficiently. If more knowledge about the influences and properties of the transition phase are available, DRPs can be applied faster and designed in a better way.

To identify the influences on the transition phase, a system analysis has been conducted. The analysis has been grouped into the domains of resources, external and internal factors. External factors can normally not be influenced whereas additional resources enable a larger freedom in dispatching disrupted situations. However, to increase available resources opposes prevailing economic requirements so that positive influences can be carried out only with limitations. Internal factors in contrast offer a large potential for improvements. Here, standard processes help to improve and accelerate communications, for example. Another starting point for improvement is the choice and design of the applied dispatching measures. Here it is important to keep in mind that unintended negative effects counteract the intended positive effects.

To complement the theoretical considerations, a case study which investigates the influences and properties of the transition phase on the example of two German urban railway networks has been conducted. In these two networks DRPs have already been implemented for five and ten years. For the case study delay reasons and locations of as well as departure times from starting stations have been analyzed. From the case study it became clear that the three major delay reasons are congestions, gradual delays and 'soft' factors like personnel availability. For the presented paper, only the reasons for congestions were analyzed in detail. Congestions during the DRP application occurred primarily at turning or deviation stations. Obviously it is not sufficient to assume that capacities of a through station will be adequate if this station is used as a DRP turning station – even if there are fewer trains. The learning is that the capacity use during the DRP transition phase has to be investigated thoroughly.

Future work

The research on DRPs, especially on their transition phase, is only beginning [KROON, 2011] and in the course of the first investigations of this domain several topics have been identified for further research. As mentioned in the presented paper, models explaining different effects on the length of the transition phase are currently developed. Besides focusing on the transition phase, the returning to regular operations after a DRP has been applied has to be investigated further as well.

Furthermore, most existing knowledge and practical DRP applications concentrate on urban passenger railway systems. But these homogeneous systems are only a part of existing railway systems – and by far not the largest. Regional passenger transportation has an important market share too, but runs on networks with mixed traffic. Here, DRPs are not yet comprehensively implemented. As DRPs have proven to be a suitable measure to ensure an acceptable level of operations during disruptions in single train networks, it is obvious to consider the use of DRPs in the context of mixed traffic.

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