The role of Automated train operation in a main line context

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***Abstract*—After being used only in metro systems, train automation is gradually being introduced in other railway contexts. In Australia, a long-distance iron ore haul project has been successfully implemented. But a main line where trains are running automated along the track isn't in operation jet. In this thesis, the impact an automation of the railway service has is evaluated. For this purpose, data of the delays in today's operation on the considered is analysed and compared with the obtained data from the simulations in OpenTrack. Different scenarios with a different number of courses automated has been simulated to get a detailed understanding of the changes automated train operation implicates. During the examination, it became obvious that for main line railways, the automation of the rolling stock can't be done alone without major difficulties because of changed behaviour of the trains.**

Keywords— train automation, actual delay, improvements

I. INTRODUCTION

The idea of automating train operation isn't a phenomenon only appearing in the last few years. Since nearly half a century, automated trains are traveling in different metro systems all around the world. Over these years, the system proved its beneficial characteristics such as improved punctuality, shorter travel time, fewer incidents and disruptions due to human error and an optimized energy usage. Through the last decade, main-line operators tried to utilize this technic for their own network.

In this thesis, the specific impact of the gradually automation of one SBB main line was evaluated. The line heads from Zürich HB along the western coast of lake Zürich eastbound towards Sargans and Chur. All the evaluation has been done for only one direction of travel, since both directions can operate independent from each other.

II. EVALUATION OF TODAY'S OPERATION

A. *Evaluation of the delay pattern*

The SBB publishes for each day the arrival and departure data on their Open Data Platform [1]. The data of 4 consecutive working days has been taken as raw material. Out of this data, the average arrival and departure delay of all courses per station has been determined. With this information, some characteristics of the examined railway line became clear such as sections where the courses become systematically delayed. In the next step, the arrival and departure delay per course and station were plotted (see Fig. 1 as an example) and the corresponding averages per station calculated.

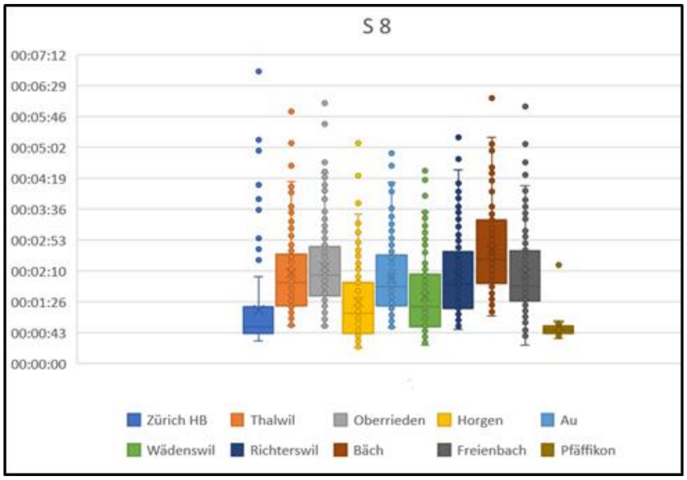


Fig.1: Departure delay plot of the S8 course

These findings were used in the simulation part of this thesis to calibrate the initial delays, and the average achieved performance per course.

B. *Critical courses*

After having investigated the behaviour of each course separately, the graphical timetable [2] has been analysed to discover potential critical courses, which may hinder a following course if delayed too much. These courses are predesignated to be automated for a maximum of stability in the network.

III. SIMULATIONS IN OPENTRACK

A. *Set-up and reference simulation*

In the set-up, two general things for the simulations following had to be defined. First, the time interval in which the simulation should be performed. This interval was fitted the way, every course ran at least twice during one simulation. Second, the dwell time for each course was defined. The courses were distributed into 2 categories with a fixed dwell time per station each. For all the S-Bahn's traveling on the line, a dwell time of 55 seconds and for the remaining courses one of 120 seconds was evaluated from the data provided by the Open Data Platform [1].

In the reference simulation, the evaluated departure delays should be reconstructed. With the dwell time and the initial delay fixed, the average performance of each course had to be adjusted until the courses matched the evaluated departure delay pattern. This simulation will be the reference for the following simulations.

TRAIN	INITIAL DELAY	PERFORMANCE	TRAIN	INITIAL DELAY	PERFOMANCE
IC 3	2:42	90 / 90	S2	1:33	95 / 95
ICE	2:45	87 / 87	S4	1:27	95 / 95
IR 13	1:54	95 / 95	S8	2:06	99 / 99
RJ/NJ	2:29	90 / 90	S12	1:25	96 / 96
RE	2:10	95 / 95	S25	1:38	90 / 90

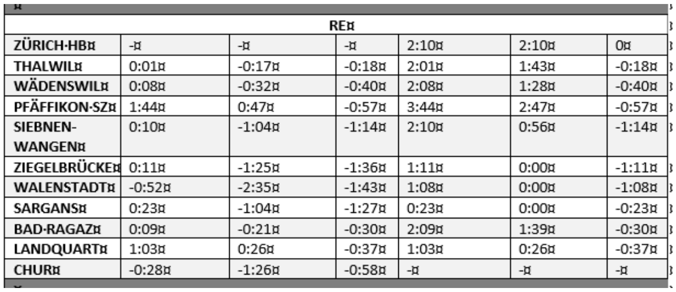
Tab.1: Initial delay and performance on time / delayed per course

B. *Gradually automation*

In the simulation part, several different scenarios with different number and combination of courses were made. Each simulation is compared with the reference simulations and rated whether this set-up was good in terms of generating the largest benefit possible or not. For a better comprehension: The first and fourth column list the reference arrival and departure delay, in the second and fifth the simulated arrival and departure delay and the last two columns are the difference between both arrival delays and departure delays respectively.

C. *General conclusions of the simulations*

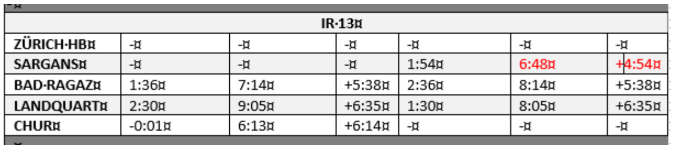
Depending on the number of courses automated, a different pattern in which courses should be running with this feature is chosen. For few courses, it makes sense to chose only courses which have no other traveling shortly before them. But then, the timetable needs to be adjusted, otherwise the gain in time will be lost while waiting in the station as table 2 illustrates.



RE¤						
ZÜRICH·HB¤	-¤	-¤	-¤	2:10¤	2:10¤	0¤
THALWIL¤	0:01¤	-0:17¤	-0:18¤	2:01¤	1:43¤	-0:18¤
WÄDENSWIL¤	0:08¤	-0:32¤	-0:40¤	2:08¤	1:28¤	-0:40¤
PFÄFFIKON·SZ¤	1:44¤	0:47¤	-0:57¤	3:44¤	2:47¤	-0:57¤
SIEBNEN-WANGEN¤	0:10¤	-1:04¤	-1:14¤	2:10¤	0:56¤	-1:14¤
ZIEGELBRÜCKE¤	0:11¤	-1:25¤	-1:36¤	1:11¤	0:00¤	-1:11¤
WALENSTADT¤	-0:52¤	-2:35¤	-1:43¤	1:08¤	0:00¤	-1:08¤
SARGANS¤	0:23¤	-1:04¤	-1:27¤	0:23¤	0:00¤	-0:23¤
BAD·RAGAZ¤	0:09¤	-0:21¤	-0:30¤	2:09¤	1:39¤	-0:30¤
LANDQUART¤	1:03¤	0:26¤	-0:37¤	1:03¤	0:26¤	-0:37¤
CHUR¤	-0:28¤	-1:26¤	-0:58¤	-¤	-¤	-¤

Tab.2: example for a course hindered by its own timetable

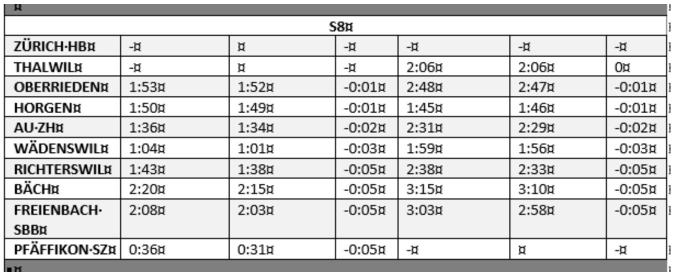
When the share of automated courses increases, an automation of an entire chain of following courses is the best way no potential of the automation is lost due to train bunching. But with an increasing number of automated courses, not all conflicts in terms of catching the preceding course up or mixing of the order the courses travel can be prevented anymore. Table 3 shows what can happen, when the order of the courses gets messed up.



IR·13¤						
ZÜRICH·HB¤	-¤	-¤	-¤	-¤	-¤	-¤
SARGANS¤	-¤	-¤	-¤	1:54¤	6:48¤	+4:54¤
BAD·RAGAZ¤	1:36¤	7:14¤	+5:38¤	2:36¤	8:14¤	+5:38¤
LANDQUART¤	2:30¤	9:05¤	+6:35¤	1:30¤	8:05¤	+6:35¤
CHUR¤	-0:01¤	6:13¤	+6:14¤	-¤	-¤	-¤

Tab.3: example of a course who is badly delayed because another travels first

With an increasing number of courses automated, the least beneficial courses are left the only one's to be unautomated. From this point, it doesn't make sense to automate further courses. Different to metro systems where all courses on a line need to be automated to be the most beneficial, on a main-line some courses should be left unautomated since the further effort to automate such courses can't be justified by the gain in travel time and delay reduction achieved. Table 4 shows the best example, where automation doesn't make sense anymore. The S8 is already running at 99% performance in manual mode, so the potential delay reduction is too small.



S8¤						
ZÜRICH·HB¤	-¤	¤	-¤	-¤	-¤	-¤
THALWIL¤	-¤	¤	-¤	2:06¤	2:06¤	0¤
OBERRIEDEN¤	1:53¤	1:52¤	-0:01¤	2:48¤	2:47¤	-0:01¤
HORGEN¤	1:50¤	1:49¤	-0:01¤	1:45¤	1:46¤	-0:01¤
AU·ZH¤	1:36¤	1:34¤	-0:02¤	2:31¤	2:29¤	-0:02¤
WÄDENSWIL¤	1:04¤	1:01¤	-0:03¤	1:59¤	1:56¤	-0:03¤
RICHTERSWIL¤	1:43¤	1:38¤	-0:05¤	2:38¤	2:33¤	-0:05¤
BÄCH¤	2:20¤	2:15¤	-0:05¤	3:15¤	3:10¤	-0:05¤
FREIENBACH·SBB¤	2:08¤	2:03¤	-0:05¤	3:03¤	2:58¤	-0:05¤
PFÄFFIKON·SZ¤	0:36¤	0:31¤	-0:05¤	-¤	¤	-¤

Tab.4: uneconomic automated course S8

IV. CONCLUSION

After considering these simulations, some of the main challenges when automating the main line traffic became clear. Because of the different manual performances of the courses, they gain different amount of time while traveling. This is the most incisive difference compared to automated train operation in metro systems. Because of this circumstance, adjustments in the timetable and the order at which the courses are traveling must be done. For courses which are gaining a lot of time, the departure time at the stations need to be earlier so no unnecessary waiting at the station occurs. For courses who get stuck at a station because another course departed earlier, the departure time should be later.

One additional problem with the automation of main line operations are the other connecting lines. If the timetable of certain courses gets adjusted, this has also an impact on the other lines. So, the adjustment should be compatible with all other lines touched by the course.

The last main difficulty concerning the automation is how the delay reduction is used. The main motivation in automating trains is to reduce delay. If the timetable now gets adjusted the way unnecessary waiting at the stations is minimised, no potential is left to catch up delays if necessary. So, a trade-off between travel time reduction and network stability need to be done.

REFERENCES

[1] SBB (2018) Swiss Public Transport Open Data Platform, https://opentransportdata.swiss/de/cookbook/ist-daten/.

[2] Fahrplanfelder CH (2018) offizielles Kursbuch, https://www.fahrplanfelder.ch/de/archiv/grafische-fahrplaene.html