

## Using the WSA Method for ARS Application in the Czech Republic

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### Abstract

The paper deals with the possibilities of the Automatic Route Setting System application in the Czech Republic. It proposes an original approach to evaluating the railway stations on the Czech railway network using the Weighted Sum Approach. In the paper, the authors define the criteria to be assessed within the Weighted Sum Approach and determine their weight. After the evaluation of the Weighted Sum Approach, the ranking of stations according to their suitability for the application of the Automatic Route Setting System will be determined in order to maximize the benefits of the Automatic Route Setting System. The aim of the paper is to propose a solution methodology and its application to a selected sample of several railway stations.

**KEY WORDS:** *automatic route setting system, weighted sum approach*

### 1. Introduction

Nowadays, emphasis is placed on effective decision-making in the process of operational management of railway transport. In rail traffic operational management, timely and correct decision-making on train movements is particularly important in view of the problems of exhausted line capacity (especially around major cities) and increasing customer demands for timely and reliable transport. Optimal decisions will increase the economic efficiency of the rail transport system itself. One way to ensure this is to automate the routine activities of traffic management staff. One such automation tool is the Automatic Route Setting System (ARS) function. To use this function effectively and to maximize potential benefits, it is necessary to decide on which lines/stations its application is appropriate and, conversely, on which stations the benefits are less due to the nature of the traffic. One of the management decision-making methods can be used to do this. For the purpose of this paper, the Weighted Sum Approach (WSA) method was chosen.

### 2. The WSA Method

The Weighted Sum Approach method (WSA) is one of the methods of multi-criteria decision making [1]. It is used to evaluate the variant  $X_i$  from the set of variants  $I$  according to the criterion  $Y_j$  from the set of criteria  $J$ . Each criterion has its own weight. For each of the variants, the total utility of the variant is calculated considering all the criteria. The option with the highest total utility is selected. The utility value is based on the classification of the criterion. The classification determines whether the criterion is a minimizing criterion (the benefit is the saving compared to the highest value) or a maximizing criterion (the benefit is the maximum value, e.g. the permeability of the rail transport route). For a correct implementation of the WSA method, it is necessary to unify all criteria into either maximizing or minimizing [2].

The principle of the WSA method is given in [3]. The procedure and application of the WSA method is given in [4].

### 3. Characteristics of the Research Topic

The WSA method will be applied in the Automatic Route Setting System (ARS). The main objective of the ARS function is to automatically provide basic and frequently recurring routine service operations for the control of the interlocking system. The dispatcher is able to fully concentrate on planning the optimum prospective traffic situation, most often resolving traffic conflicts that arise, without having to deal with the frequently recurring service operations of the interlocking system. The instructions to the interlocking to set the train route are given by the ARS on the basis of the timetable in the Traffic Management System (TMS) or the actual position of the train. In the Czech Republic, a combination of both approaches is used, which complement each other. Usually, train routes are set in accordance with the train timetable, but in sections where there is a significant reduction in journey times, the actual position of the train in the interlocking system is also monitored. The aim is to set the train route in an optimally timely manner to maximize the smooth running of all trains and not to reduce the capacity of the transport infrastructure. At the same time, the

timely resolution of forward-looking traffic, i.e. to make it conflict-free, is to the benefit of every rail user. For example, passengers will receive information about planned train delays earlier [5].

The command to set a train route is the basic command of the ARS. Along with this, ARS also contains other commonly used commands. One of them is the command for automatic train turnaround at the terminating station (extinction of the terminating train number in the interlocking system and insertion of the turnaround train number) without any dispatcher intervention [6].

When dealing with emerging traffic conflicts, timetable deviations and difficult to predict traffic situations (e.g. shunting), the dispatcher in the Czech Republic has the possibility to influence the operation of the ARS in the TMS using the Layout Criteria. The dispatcher can set a layout criterion for each train route that currently prevents this route from being set and also select when the train route should be automatically set. Alternatively, it can intervene directly in the signaling control system (an operator tool is called as JOP) and thus perform the task itself, regardless of the automation function [6]. Any such dispatcher intervention thus requires considerable attention of the dispatcher during a given time period, or periodic attention.

Therefore, the application of ARS is particularly suitable where the largest proportion of routine service tasks is compared to the solution of original (specific) traffic situations.

The benefit is to improve the efficiency of railway traffic management on lines controlled remotely either from the Central CTC (CDP Praha and CDP Přerov), from Regional CTC throughout the Czech Republic (RDP) or from individual stations controlled from the JOP. The ARS application also corresponds to the strategic objectives of the infrastructure manager (Railway Administration, state organization) in the field of infrastructure development. The strategic objectives include, among others, digitalization and increasing the capacity of the lines [7].

Fig. 1 shows where ARS in the Czech Republic is activated (green), projected (blue) and being prepared (yellow) as of May 2024. It is clear from the figure that ARS is mainly applied on main lines, suburban lines with heavy passenger train traffic and a few lines of regional importance (mainly in the north-west of the Czech Republic). These lines of regional importance are usually connecting lines to the main lines. On the other hand, on the network of regionally important lines, which do not serve the function of suburban lines or lines connecting to transit corridors, ARS is not applied anywhere in the Czech Republic today, with the exception of the Klatovy - Železná Ruda-Alžbětín line.

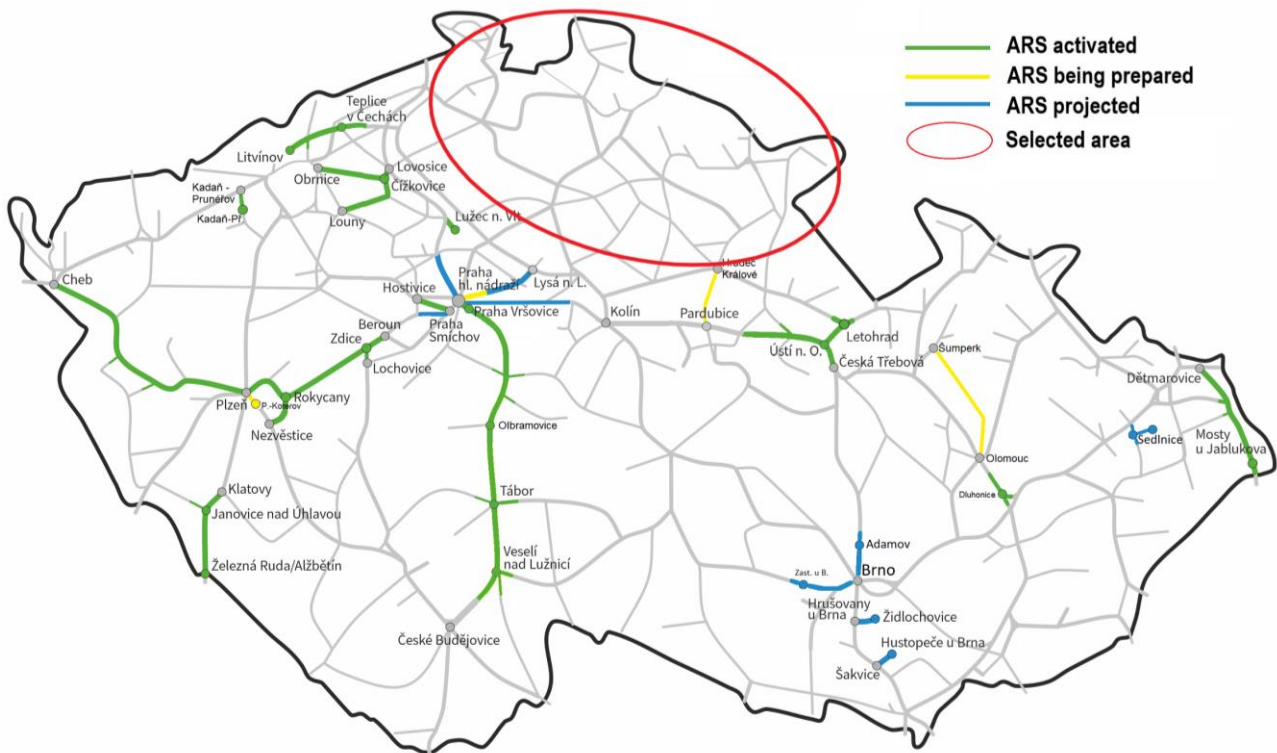


Fig. 1 Map of the railway network in the Czech Republic showing the use of ARS

The authors will consider in this paper the possibility of applying the ARS in the network of railways of regional importance, which are not primarily connected to the main network of railways. The densest network of regionally important railways is located in the north of the Czech Republic, as shown by the red circle in Figure 1. All these lines are single-track, non-electrified, with max speeds up to 100 km/h [8] and nowadays ARS is not applied anywhere on them [6].

#### 4. Determination of Criteria and Selection of Stations for WSA Application (Case Study)

For the case study of the application of the WSA method, the authors selected stations in the Hradec Králové and Liberec regions in the north of the Czech Republic, which are equipped with electronic interlocking system and are usually part of the remote control of lines. Electronic interlocking system is a necessary condition for the ARS function, therefore other stations are not included in the selection. The lines on which the stations are located are highlighted in Fig. 2.

The application of the ARS will be evaluated for:

- The controlled area Bohuslavice nad Metují – Hronov (controlled from Regional Traffic Control Centre in Náchod): stations Bohuslavice nad Metují, Václavice, Náchod, Hronov.
- The controlled area Jaroměř (not included) – Železný Brod (controlled from Regional Traffic Control Centre in Stará Paka): stations Dvůr Králové nad Labem, Bílá Třemešná, Mostek, Horka u Staré Paky, Stará Paka, Košťálov, Semily.
- The controlled area Liberec (not included) – Tanvald (controlled from Regional Traffic Control Centre in Liberec): stations Vesec u Liberce, Jablonec nad Nisou, Smržovka, Josefův Důl, Tanvald.
- The controlled area Frýdland v Čechách – Bílý Potok pod Smrkem (controlled from Regional Traffic Control Centre in Frýdland v Čechách): stations Frýdland v Čechách, Raspenava, Bílý Potok pod Smrkem.
- Stations Jaroměř and Trutnov-střed.

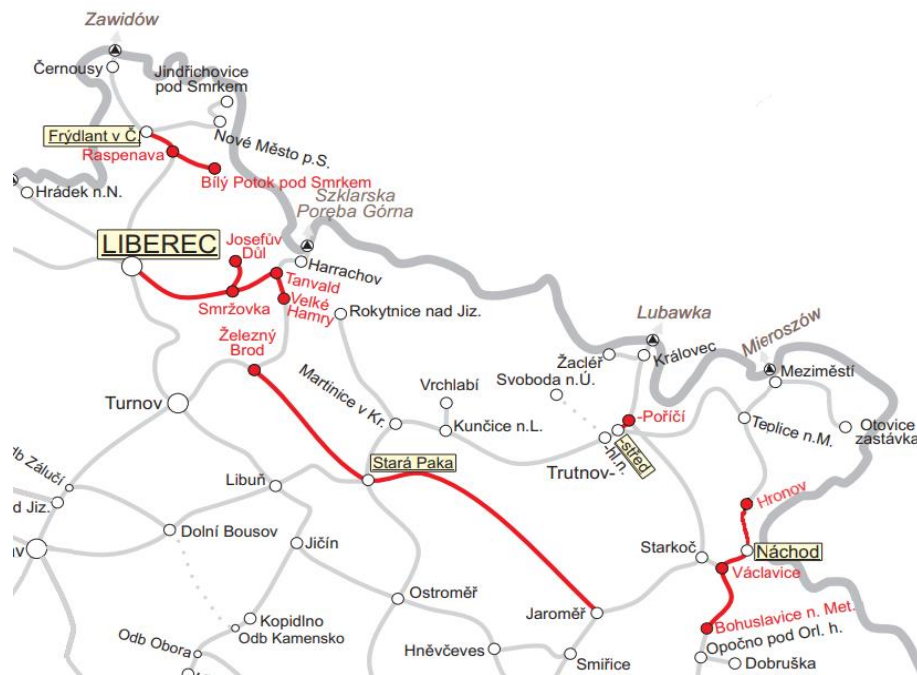


Fig. 2 Centralized traffic control lines in the north of the Czech Republic [8]

For decision making based on the WSA method, the authors set the following criteria: infrastructure attributes, number of trains/day, number of train crossings/day, number of passenger transfers/day, expected rate of shunting/day, number of runs in sequence/day and number of train turnarounds/day. The selected criteria are commented by the authors below Table 1.

The weighting of the criteria was done using the Saaty matrix and the resulting weights of the criteria are shown in Table 1.

Table 1

Weights of criterions

Criterion "i"	Weight of criterion $w_j$
Infrastructure attributes	0.4811
Number of trains/day	0.1602
Number of train crossings/day	0.0704
Number of passenger transfers/day	0.0313
Expected rate of shunting/day	0.0602
Number of runs in sequence/day	0.0367
Number of train turnarounds/day	0.1602

Infrastructure attributes are the basic condition for the application of the ARS. It is a technical necessity to equip the station with electronic interlocking system. It is used in 469 stations of 1,214 stations in the Czech Republic [9]. In the Czech Republic StationSWing ESA 51, StationSWing ESA 44 and K-2002 are developed and used [10-12].

In addition to equipping the station with an electronic interlocking system, an important prerequisite for the possibility of ARS application is also the condition of the station's infrastructure in the area of passenger access to the platform. This is defined in the Technical specifications of the ARS [13]. If the passenger access to all trains is fully secured, then the station is rated 1. The fully secured access means access via underpass or overpass, track crossing warning light for passengers or access from outside the track. If the passenger access is via a central crossing and it is secured by a main signal for trains (no signal for passengers), then the station is rated 0.5. Otherwise the station is rated 0 and ARS shall not be applied in such a station. Therefore, the highest priority has been assigned to this criterion.

The other criteria always correspond to the number of train occurrences per average working day in the timetable valid at the beginning of 2024 (in the Czech Republic a regular timetable change takes place in June). The numerical values of these criteria were determined on the basis of [8]. The number of trains, the number of runs in a sequence, the number of train crossings and the number of train turnarounds per day are properly provided by the ARS function, so these criteria are determined as maximization criteria (the aim is to provide as many of these operations as possible automatically). The organization of passenger transfers and shunting is still the full responsibility of the dispatcher, so it is appropriate to deploy ARS where these operations are as few as possible. These criteria are thus minimization criteria.

The expected rate of shunting for an average working day was determined on the basis of a qualified estimate by the authors. This takes into account the freight trains with handling in a given station, the number of locomotive bypassing wagons during passenger train turnarounds (occurs mainly in Náchod) [8] and possible sidings and their service in the form of shifting (locomotive depot in Stará Paka, industrial areas). These criteria are also considered minimization criteria.

The default criterion matrix is given in Table 2.

Table 2

Default criterion matrix

Station	Infrastructure attributes	Number of trains/day	Number of train crossings/day	Number of passenger transfers/day	Expected rate of shunting/day	Number of runs in sequence/day	Number of turnarounds /day
Hronov	0.5	51	10	0	4	1	5
Náchod	0.5	74	24	2	13	9	12
Václavice	0.5	95	17	47	0	3	15
Nové Město n. Met	0.5	33	1	0	2	1	0
Bohuslavice n. Met	0	33	0	0	0	1	0
Jaroměř	1	110	28	36	3	5	19
Dvůr Králové n. Lab.	0.5	34	9	0	1	1	0
Bílá Třebešná	0.5	32	0	0	0	0	0
Mostek	1	32	6	0	0	0	0
Horka u Staré Paky	0.5	36	2	0	1	0	0
Stará Paka	0.5	93	32	192	8	5	11
Košťálov	0	38	4	0	2	1	0
Semily	1	43	8	0	1	1	1
Vesec u Liberce	1	62	18	0	0	0	0
Jablonec nad Nisou	0.5	62	27	0	2	0	0
Josefův Důl	0	46	0	0	0	0	23
Smržovka	1	106	18	68	0	0	22
Tanvald	0.5	99	22	75	0	0	16
Frydlant v Čechách	0.5	72	10	0	4	0	4
Raspenava	0.5	104	18	36	0	0	7
Bílý Potok p. Smrkem	1	38	0	0	0	0	19
Trutnov-střed	0	82	11	18	11	2	0
	MAX	MAX	MAX	MIN	MIN	MAX	MAX

After performing the WSA, the benefits of each variant  $X_i$  in the evaluation of criterion  $Y_j$  and the total utility of the variant  $X_i$  were calculated, which is shown in the right column of Table No. 3.

Table 3

## Resulting weighted utility matrix

Station	Infra. attributes	Number of trains/day	Number of train crossings /day	Number of passenger transfers day	Expected rate of shunting /day	Number of runs in sequence /day	Number of turns/day	Total weighted utility:
Hronov	0.5000	0.2436	0.3125	1.0000	0.6923	0.1111	0.2174	<b>0.3786</b>
Náchod	0.5000	0.5385	0.7500	0.9896	0.0000	1.0000	0.5217	<b>0.4473</b>
Václavice	0.5000	0.8077	0.5313	0.7552	1.0000	0.3333	0.6522	<b>0.5034</b>
Nové Město n. Met	0.5000	0.0128	0.0313	1.0000	0.8462	0.1111	0.0000	<b>0.3311</b>
Bohuslavice n. Met	0.0000	0.0128	0.0000	1.0000	1.0000	0.1111	0.0000	<b>0.0977</b>
Jaroměř	1.0000	1.0000	0.8750	0.8125	0.7692	0.5556	0.8261	<b>0.7950</b>
Dvůr Králové n. Lab.	0.5000	0.0256	0.2813	1.0000	0.9231	0.1111	0.0000	<b>0.3554</b>
Bílá Třebešná	0.5000	0.0000	0.0000	1.0000	1.0000	0.0000	0.0000	<b>0.3321</b>
Mostek	1.0000	0.0000	0.1875	1.0000	1.0000	0.0000	0.0000	<b>0.5858</b>
Horka u Staré Paky	0.5000	0.0513	0.0625	1.0000	0.9231	0.0000	0.0000	<b>0.3400</b>
Stará Paka	0.5000	0.7821	1.0000	0.0000	0.3846	0.5556	0.4783	<b>0.4797</b>
Košťálov	0.0000	0.0769	0.1250	1.0000	0.8462	0.1111	0.0000	<b>0.1075</b>
Semily	1.0000	0.1410	0.2500	1.0000	0.9231	0.1111	0.0435	<b>0.6122</b>
Vesec u Liberce	1.0000	0.3846	0.5625	1.0000	1.0000	0.0000	0.0000	<b>0.6738</b>
Jablonec nad Nisou	0.5000	0.3846	0.8438	1.0000	0.8462	0.0000	0.0000	<b>0.4438</b>
Josefův Důl	0.0000	0.1795	0.0000	1.0000	1.0000	0.0000	1.0000	<b>0.1203</b>
Smržovka	1.0000	0.9487	0.5625	0.6458	1.0000	0.0000	0.9565	<b>0.7531</b>
Tanvald	0.5000	0.8590	0.6875	0.6094	1.0000	0.0000	0.6957	<b>0.5058</b>
Frýdlant v Čechách	0.5000	0.5128	0.3125	1.0000	0.6923	0.0000	0.1739	<b>0.4177</b>
Raspenava	0.5000	0.9231	0.5625	0.8125	1.0000	0.0000	0.3043	<b>0.5136</b>
Bílý Potok p. Smrkem	1.0000	0.0769	0.0000	1.0000	1.0000	0.0000	0.8261	<b>0.5849</b>
Trutnov-střed	0.0000	0.6410	0.3438	0.9063	0.1538	0.2222	0.0000	<b>0.1727</b>

From the calculated total utilities it is evident that the most suitable station for the application of ARS in real traffic is station Jaroměř (total weighted utility 0.79), followed by Smržovka, Vesec u Liberce, Semily, Bílý Potok pod Smrkem and Mostek. It thus appears that the WSA method can reliably take into account the infrastructure attributes criterion, since in all of these stations the passenger access to the all platforms is fully secured (without crossing the tracks by passengers or track crossing warning light for passengers, defined under Table 1). On the other hand, the stations where according to [13] ARS cannot be applied (Bohuslavice nad Metují, Košťálov, Josefův Důl and Trutnov-střed) have the lowest overall utility.

### 3. Conclusions

The possibility of applying the weighted sum method (WSA) for selecting a suitable station to deploy the ARS function in practice was verified in this paper. The authors established the criteria by which the stations were judged and their weighting. The following maximization criteria were identified and quantified according to a defined key: infrastructure attributes, number of trains per day, number of train crossings per day, number of runs in sequence per day and number of train turnarounds per day. In addition, the minimization criteria of number of passenger transfers per day and expected rate of shunting per day were defined, as these tasks are not addressed by the ARS function.

The implementation of the WSA has proved that it can recognize the infrastructure requirements very well if this criterion has a preference over other operational criteria (preference can be provided by e.g., Saaty's method for weighting criteria). Stations with fully secured platform access are proved to be the most suitable for the application of the ARS (their ranking depended on other criteria). On the other hand stations that are not with fully secured platform access at all have the lowest overall weighted utility around 0.1.

The aim of the paper was to demonstrate the possibilities of using the WSA method in the decision-making process of introducing rail traffic management automation.

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