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BENEFITS OF REMOTE CONTROL ON THE RAILWAY LINES

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Abstract. Railway transport in the Czech Republic largely uses transit corridors, which are significantly more used than the rest of the railway network. This assumption leads to an increase in the safety of these lines and gradual double-tracking. All these aspects lead to the fact that the given lines are controlled from dispatching centres, while other lines are controlled from regional dispatch offices. The above parameters also apply to other non-corridor but still busy lines. It can therefore be concluded that this trend of remote control brings significant operational and technological advantages. The most visible benefit is the personnel saving of operational employees, but another significant benefit, which is not so obvious at first glance, is the benefit of a more efficient organization and management of railway transport. This impact brings the effect of smoother traffic, which manifests itself in a lower burden on the environment, thanks to fewer train starts and stops, or there will be no complete stop, but only a reduction in train speed. Furthermore, this influence is evident in the more frequent overtaking of trains not in railway stations, but in inter-station sections. All these advantages lead to an increase in an important operational indicator, which is the throughput of the track.

Keywords: Railway transport, railways, central dispatching, remote control, interlocking system, railway operation.

1. Introduction

In order to understand the benefits of the remote control, it is necessary to approach the ways of organizing rail transport for remote and local control. This analytical part brings us results in the form of different operational-technological principles that distinguish these two types of control. The effects of remote control need to be demonstrably proven. This impact is best demonstrated on the completed train traffic graph (TTG). Therefore, the fulfilled TTG is compiled for individual types of control and subsequently compared using the proposed point system. The section Staré Město u Uherského Hradiště – Přerov was chosen for the relevant input data for the creation of TTG, or real parameters of trains and track. An analysis of the trains was also carried out on this section. Based on the analysis of the trains, it is possible to compile typical trains and, thanks to these relevant documents, to compile a prospective TTG or the TTG, which is displayed to dispatchers and track dispatchers in operational applications. This same "baseline" (similar decision-making information in the form of forward-looking TTG) then serves as a reference element for evaluating the benefits of remote control. The assessment of benefits is based on a comparison of the TTGs achieved for each type of control, namely local or remote control. The reasons for the different TTGs met are described in the following paragraphs.

2. Local Control

Local control is a method of control where operating employees organize the movement of railway vehicles from the traffic office located in the given railway station. The disadvantage of this driving style is the flow of traffic. With this method of control, the operating employee usually does not have a complete overview of the traffic situation in the surrounding transport facilities, but only a partial one. The most common tool that a transport employee has available for information about the traffic situation in nearby transport facilities is the Train Track Position (TTP) application, see Figure 1.

This application shows the fulfilled TTG on the left part and the future traffic on the right part of the screen, the interface is a green line with the current time. However, the disadvantage of the TTP application is that the train position data is not displayed in real time, but with a delay of up to 180 s. Another major disadvantage is that the operating employee in local control does not have information about the shift, occupation of tracks, safety labels, malfunctions and defects that take place in neighbouring railway stations. He only has an overview of what is happening in his railway station, this situation is shown in Figure 2.

All these aspects are further enhanced by the fact that communication between the individual operating employees in the given transport companies is in real time, but by telephone, while the given problem is often difficult to explain and understand, and the time required for understanding is significantly ex-

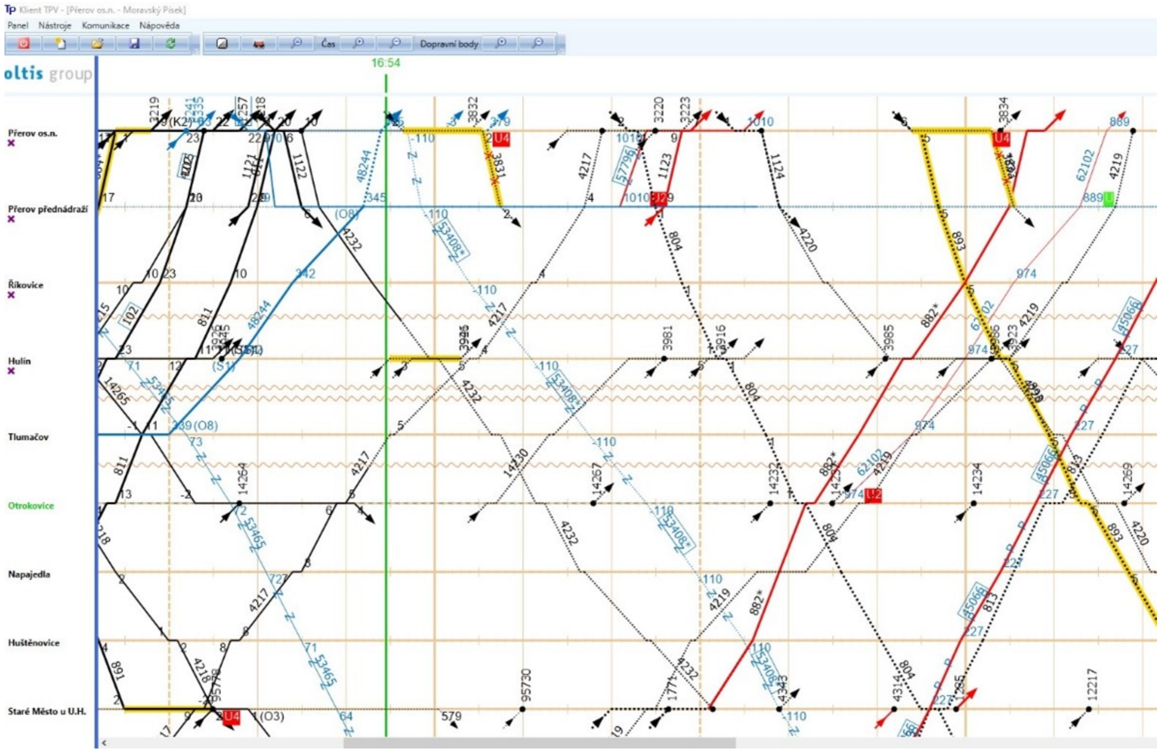


Figure 1. Application Train Track Position.

Figure 2. Scheme for local control.

tended, compared to a situation where dispatchers are in the same hall (remote control method) and solve the problem together. It follows from this that in any non-standard situation (driving against the correct direction, shift, extraordinary event, failure, fault, lockout, established safety label or waiting for connecting trains, etc.) this information needs to be immediately passed on, or reported by phone to the operating staff in concerned transport companies.

Due to the large number of actions resulting from operational situations (both standard and extraordinary), there is no telephone transmission of information about the situation in the concerned transport company. In the surrounding depots, there are erroneous considerations about the operational situation in the affected depot, which are exacerbated by the inaccurate time position of the trains, caused by the out-of-date TTP. Furthermore, this set of information noise is supported by the fact that some situations when organizing rail transport (shifting, occupation of transport tracks, waiting for a connecting train, etc.) do not need to be reported to neighbouring transport authorities.

An example of a mistaken reasoning can be observed when comparing Figures 3 and 4. The dispatcher in the figures shown, due to the lockout (orange square), must use only one track. A side effect of the lockout is that the freight train may stop on the passing track. However, he does not have to report this information to anyone. In the neighbouring traffic house, a false impression may arise that, as always, the freight train will stop on the front track and the passenger train will

Figure 3. An example of a mistaken consideration of the implementation of a train route in the railway station.

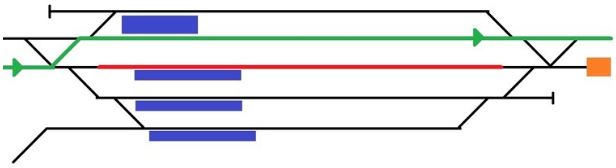


Figure 4. An example of the real realization of a train route in the railway station.

depart from the main track, which is a continuation of the track from the correct direction. The consequence of this misconception is that even if the predicted departure of the train from the shown depot is the same, the arrival at the neighbouring depot is different because the passenger train does not take a turn at the time of departure, but already travels at track speed.

All these aspects are manifested in two-track locally controlled lines in such a way that each transport company uses one track for one direction and the other track for the other direction, see Figure 5. Furthermore, unused time windows are often neglected, caused by lengthy information submission and the need for a precise description the given traffic situation to non-participating staff in secondary locally controlled transport companies. The time window refers to the free capacity of the transport route, which is usually not used for this type of control.

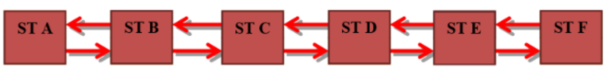


Figure 5. Simplified scheme of track traffic for local control.

3. Remote Control

Remote control has many advantages. The basic advantage associated with remote control is a comprehensive overview of the traffic situation, usually not only in the controlled area. This complex information is conveyed using large-area display (VEZO) [1]. The VEZO system is used for overview display of logically integrated sections at central dispatch workplaces (CDP) using the system of remote control of the security device (DOZ). The advantage of an overview of the traffic situation, outside the controlled area of the given CDP dispatcher, is reduced telephone, usually also oral communication, because the dispatcher can find out the given information himself by looking at the VEZO, and thus there is no loss of suitable time windows. These time windows can also be used for trains of lower categories, which would otherwise usually stand on the "edges" of the controlled areas of individual dispatchers. Office of the dispatching centre is shown in the Figure 6.

A track dispatcher usually controls more than one transport company. This fact makes it possible to shorten the operating intervals. Time is saved even in standard situations, by using the "Automatic rotation of consent" function, i.e. the track dispatcher does not have to ask for consent and give it to himself. Since the remote control enables this function, this function is shown in Figure 7.

Another automatic function of DOZ is the possibility of building a train route through up to 4 transport yards. Securing train travel in the interstation section can be done in many ways. Only one method can be used exclusively for remote control, namely driving without a safety device. Savings in non-standard situations are also manifested by shortening the operating intervals. This is due to the fact that the track dispatcher controls both transport units adjacent to the interstation section, or if he does not control it, his control circuit can be changed, for example, on the basis of a teaching order. In the case of extraordinary events, the track dispatcher can operatively change his control circuit, because as a rule he has the professional competence for several positions in the given control room.

A set of precise time positions of trains, displayed on the graphic-technological superstructure (GTN) or on the relief of the track at the given workplace, or on the VEZO, forms a comprehensive overview of all situations taking place in the given control room. All these aspects are manifested in two-track remote-controlled lines in such a way that each transport company uses both track tracks for one direction and the other direction, see Figure 8.

The added value is teamwork within the controlled area in a given control room, which manifests itself in an immediate response to the given situation and the possibility of operatively changing the size of the controlled areas. Furthermore, all dispatchers in a given control room are part of a given problem and can solve it efficiently and dynamically through teamwork. As a result, the lengthy process of providing information and the need for an accurate description of the given traffic situation to non-participating employees in secondary transport facilities is eliminated.

The main disadvantage of remote control is that the transports are not physically occupied by a transport employee, even though according to the regulation of the SŽ (SŽDC) D1, the DOZ transports are occupied transports. This provision of the regulation is particularly important when managing trains by written orders, which are usually issued in case of emergency situations.

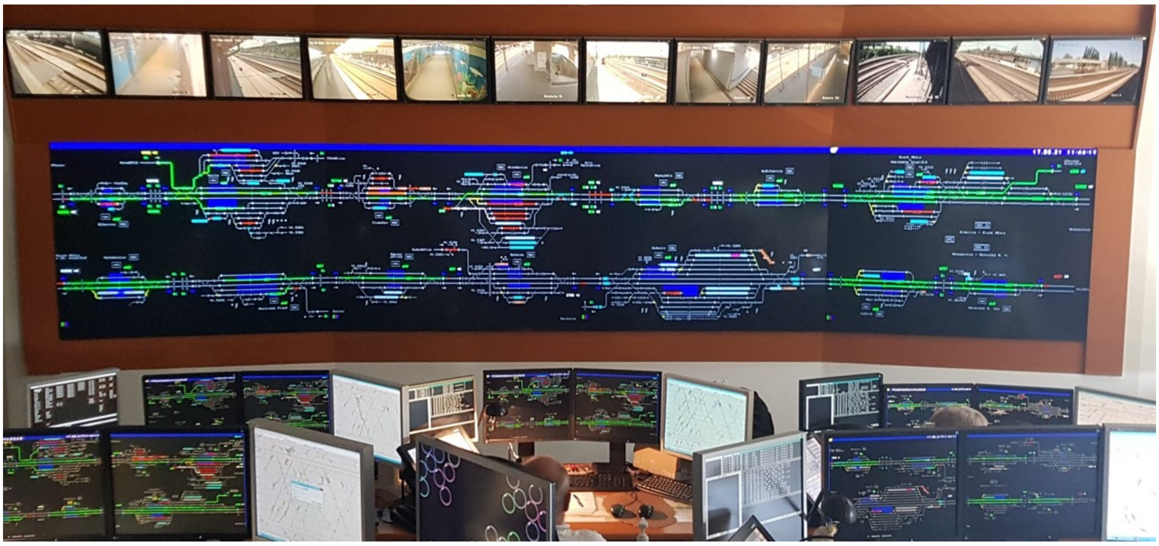


Figure 6. Large-scale display device for the Říkovice – Moravská Nová Ves line.

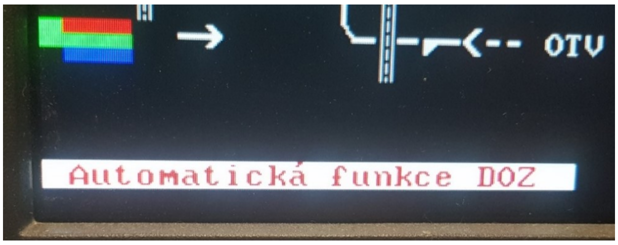


Figure 7. Sample of the technological list of DOZ functions on monitors.

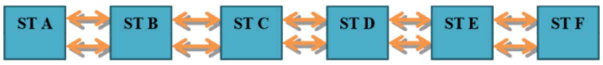


Figure 8. Simplified diagram of track traffic for remote control.

4. Materials and Methods

An analysis of the input currents of trains passing through the given edge was performed. The input stream of trains means the train structure, i.e. how many passenger trains and how many freight trains will pass through the given input edge in the monitored period. Data collection took place from 24/05/2021 to 24/06/2021, always between 10:50 and 15:00. For the purpose of this work, the entry edge is the place where the train enters the tracked part of the track (Přerov přednádraží – Staré Město u Uherského Hradiště). An analysis of the parameters of the entering train was therefore carried out at the entrance edge. These are delays for passenger trains or the type, entry time, length, weight, maximum speed and driving vehicle of a freight train.

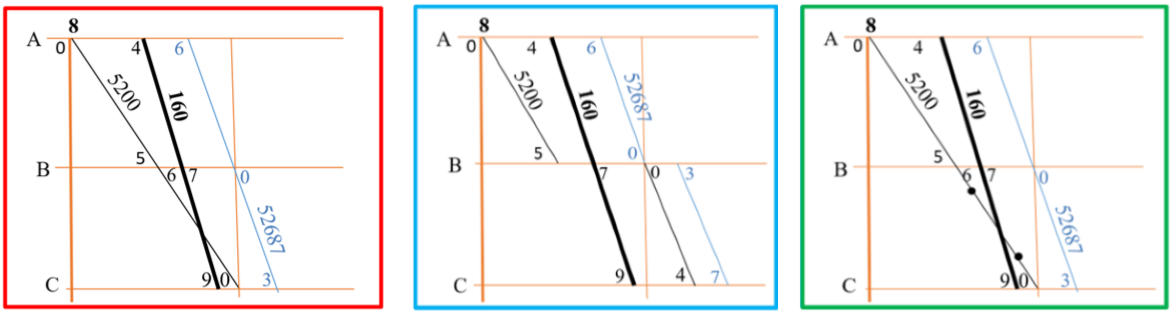
A single-phase analysis was performed for passenger trains. During the analysis, only the value of the delay that the given train had when leaving or passing through the given edge was monitored, because these trains have the same set composition throughout the monitored period.

For freight trains, the time of entering the edge, the type of train (freight express (Nex), continuous freight (Pn), locomotive train (Lv) and train in residual capacity), as well as the length, weight and maximum speed of the train were always monitored in the given period, as well as the Propulsion Vehicle (HV) series. Based on this follow-up, a two-phase analysis was performed. In the first phase, the number of trains that entered the selected edges at the monitored time was monitored. From this first part of the analysis, the average number of freight trains entering a given edge was obtained. When calculating the average, weekends were not taken into account, due to the lower intensity of freight train traffic. In the second part of the analysis, so-called "type trains" were compiled. For the assembly of typical freight trains, basic parameters were assigned for each train, namely weight, speed, length, HV series and edge entry time. These basic train parameters were determined on the basis of the most frequent frequencies of the given parameters for individual types of trains (Lv, Nex, Pn, trains with residual capacity). The resulting type trains were created on this basis.

5. Results

On the basis of the above knowledge and principles, an assessment of the benefits of remote control was prepared. These findings and benefits are explained in detail on a model example, whose fulfilled TTG was designed in accordance with the described principles of remote and local control, see Figure 9. Based on the calculation principle that is used in the model example, the resulting tables were also compiled for specific typical example whose TTG is met based on the real operation of trains on the selected track section.

The procedure for calculating the benefits of remote control. The first two columns of Table 1 are filled in



(a). Reference var., pros. transport. (b). Local control. (c). Remote control.

Figure 9. Advantage of model example number 1 remote control. *Note: these are trains: Os 5200, Ex 160, train in residual capacity 52 687.*

Type of train	Train number	Output time			The time difference between the reference variant and:		One-minute rating	Management point evaluation	
		reference variant	remote control	local control	by remote control	by local control		remote	local
Os	5200	8:10	8:10	8:14	0	4	5.24	0	20.96
Ex	160	8:09	8:09	8:09	0	0	8.57	0	0
Z	52 687	8:13	8:13	8:17	0	4	0.48	0	1.92
							Total points	**0**	**22.88**
							Conversion to percentages	**100 %**	**0 %**
							Remote control advantage expressed as a percentage	**100 %**	

Table 1. Benefit of remote control model example number 1.

based on the data provided in the reference graph of train traffic, see Figure 9. Then it is necessary to find out the times of train departures from the monitored edges. These times are determined from the reference TTG (Figure 9a), and then also for the individual types of compared controls. Then the differences of the values for remote control (Figure 9c) and local control (Figure 9b) are performed with the reference time of departure of the given train, see columns six and seven of Table 1.

Based on Table 2 and the type of train in the first column, the "One-minute rating" column is completed. The last columns "Point evaluation of the control" are created by the product of the times indicated in the columns "Time difference between the reference variant" and the "One-minute rating" column. Based on this principle, the entire table is filled in and then all the values calculated in the "Management point evaluation" columns are added up.

After adding up the obtained points, the initial results can be observed. The primary indicator is the points earned. The more points a given type of control received, the lower the quality of TTG fulfillment. The next step in calculating the point rating is to add up all points achieved. These added points form the worst possible result we can achieve. At the same time, it forms a reference figure for us to convert the obtained points into percentages, which are assigned to individual types of control. After this step, where percentages are assigned to remote and local control, it is determined by what percentage each type of control is better than the other. The result of the calculation is almost identical in all cases, as the percentages are higher for remote control. For these reasons, the percentages obtained for local control will be deducted from the percentages obtained for remote control. The resulting percentages tell us by what percentage remote control is more advantageous than local control. In this typ case, the output edge is railway station C.

Based on the analysis of the trains that run on the selected track section, type trains are assembled. Based on these relevant documents of the proposed mechanism for evaluating the benefits of remote control and the principles of train organization for remotely and locally controlled lines, TTGs are compiled, both reference and fulfilled. From the prospective or reference TTG and fulfilled TTG, a table was compiled that comprehensively analyzes the impacts of remote control on the selected line Staré Město u Uherského Hradiště – Přerov přednádraží in the monitored time. When using the calculation mechanism described above and subsequent conversion to percentages, we obtain a saving of 44.63 %. If we stick to just the point difference, we get a value of 117.52 points. If this percentage benefit is translated into financial

Type of train	Scale
Necessary auxiliary trains	9.52
Special trains in general interest	9.05
Express trains with a holiday of more than 140 km h^{-1}, including locomotive trains and sets for these trains	8.57
Fast trains with holidays at a speed of over 140 km h^{-1}, including locomotives and sets for these trains	8.10
Interstate freight express trains with a leave of more than 100 km h^{-1} inclusive and a minimum specific traction power of 2.1 kW (1 hrt)$^{-1}$	7.62
Express trains with a speed of up to and including 140 km h^{-1}, including locomotive trains and sets for these trains	7.14
Fast trains with a speed of up to and including 140 km h^{-1}, including locomotive trains and sets for these trains	6.67
Interstate freight trains with a permitted speed of more than 100 km h^{-1} inclusive and a minimum specific traction power of 2.1 kW (1 hrt)$^{-1}$	6.19
Passenger express trains, including locomotive train journeys and sets for these trains	5.71
Passenger trains, including locomotive train journeys and sets for these trains	5.24
Freight trains: national express	4.76
Freight trains: carrying passengers	4.29
Freight trains: other interstate	3.81
Freight trains: continuous	3.33
Freight trains: combination trains that are not intended for passenger train journeys according to the bullet	2.86
Freight trains: handling	2.38
Freight trains: siding	1.90
Locomotive trains	1.43
Service trains	0.95
Trains in the residual capacity of the track	0.48
Shift between railway station	0.00

Table 2. Train preferences and point rating [2].

indicators based on the 2022 Network Statement, such that for every minute of delay saved by remote control compared to local control, this saving is valued at CZK 4 [3], saving Railway management thanks to remote control CZK 188. Table 3 was compiled on the basis of these obtained data, which converted these data into time periods. Thanks to the data obtained in this way and remote control, considerable financial savings can be achieved.

Induction is a method whose conclusion is based on specific results achieved in this work. Table 4 was constructed based on induction. The data in Table 4 are taken over and supplemented with wage savings, which are generated due to the lower staffing needs of employees.

This saving is not final, it does not include the savings in traction energy and fuel resulting from smoother transport.

An example of savings is explained using a typical example in Figure 10. The illustrated situation occurs very often on the given section of the track, which is why it was evaluated financially. This benefit is evaluated in Table 4 based on the above procedure. Further, on this model example, the saving of electrical energy is calculated, see Table 5. The saving of electrical energy is realized due to the fact that the train does not stop, but passes through the given railway station at a reduced speed. The train has parameters (loco 383, weight 2289 t, length 519 m, speed 100 km h^{-1}). Passage through the Otrokovice station is reduced to a speed of 60 km h^{-1}. In this typical case, the exit edge is the Hulín railway.

We consider the price of traction energy to be CZK 3.11 per 1 kWh [6]. Based on the electricity consumption data listed in Table 6, the financial savings of the given operating situation were also calculated. This saving was calculated as the difference in electricity consumption depending on the type of control. The difference is 90 133 kWh. If we multiply the mentioned difference by the price of traction energy, we arrive at the amount of CZK 280.58, which is the amount that is saved with the remote control.

Other savings associated with the physical vacancy of railway stations are energy savings (heating, electricity, water, sewage, etc.). In addition, lower costs for protective equipment (shoes, uniforms, etc.) must be expected, since CDP employees do not need to receive them, since they do not enter the track and come into contact with passengers. In conclusion, it can be stated that the results achieved do not form a comprehensive overview of the advantages of remote control. The induction advantage described is a sig-

Interval	Přerov – Staré městou u U.H.	Conversion to 1 km remote-controlled track	Conversion to all double-tracks lines operated from CDP Přerov	All double-track lines operated from CDP Přerov and Prague	Units
Minute	0.66	0.0151	6.54	11.91	CZK min^{-1}
Hour	39.58	0.9057	392.17	714.32	CZK hour^{-1}
Day	949.89	21.7367	9 412.00	17 143.75	CZK day^{-1}
Month	28 496.84	652.1017	282 360.01	514 312.57	CZK month^{-1}
Year	346 711.58	7 933.9034	3 435 380.18	6 257 469.62	CZK year^{-1}

Table 3. Financial quantification of the benefits of remote control [3–5].

Interval	Přerov – Staré městou u U.H.	Přerov – Břeclav	Conversion to 1 km remote-controlled track	Conversion to all double-tracks lines operated from CDP Přerov	All double-track lines operated from CDP Přerov and Prague	Units
Minute	22	61	0.64	275	501	CZK min^{-1}
Hour	1 298	3 678	38.15	16 519	30 090	CZK hour^{-1}
Day	31 162	88 267	915.63	396 468	722 157	CZK day^{-1}
Month	947 460	2 683 906	27 841.35	12 055 305	21 958 474	CZK month^{-1}
Year	11 374 268	32 217 353	334 204.91	144 710 726	263 587 412	CZK year^{-1}

Table 4. Total quantification of the benefits of remote control [3–5].

Type of train	Train number	Output time			The time difference between the reference variant and:		One-minute rating	Management point evaluation	
		reference variant	remote control	local control	by remote control	by local control		remote	local
Os	14258	8:20:00	8:20:00	8:20:00	0	0	5.24	0	0
Z	52855	8:13:30	8:15:00	8:22:00	1.5	8.5	0.48	0.72	4.08
							Total points	**0.72**	**4.08**
							Conversion to percentages	**85 %**	**15 %**
							Remote control advantage expressed as a percentage	**70 %**	

Table 5. Benefit of remote control model example number 2.

(a). Reference var., pros. transport. (b). Local control. (c). Remote control.

Figure 10. Benefit of remote control model example number 2. *Note: these are trains: Axis 14258, train in residual capacity 52855.*

Interstation section/ railway station	Refernce TTG Driving time/Stay [min]	Control type Local Driving time/Stay [min]	Track / station tracks	Electricity consumption [kWh]	Remote Driving time/Stay [min]	Track / station tracks	Electricity consumption [kWh]
Huštěnovice → Napajedla	4.5	4.5	1	193.505	4.5	1	193.505
Napajedla	–	–	1	–	–	1	–
Napajdela → Otrokovice	4.5	5	1	16.775	5	1	16.643
Otrokovice	–	4	1	–	–	2	–
Otrokovice → Tlumačov	4.5	8.5	1	420.812	5	2	376.549
Tlumačov	–	–	1	–	–	2	–
Tlumačov → Hulín	4.5	4.5	1	284.104	5	2	120.986
Hulín	–	–	1	–	–	2	–
Hulín → Říkovice	6.5	6.5	1	321.130	7	1	429.951
Říkovice	–	–	1	–	–	2	–
Říkovice → Přerov před-nádraží	4.5	4.5	101	110.208	4.5	101	118.787
In total	**29**	**37.5**	**X**	**1 346.534**	**31**	**X**	**1 256.421**

Table 6. Electric energy consumption according to the model example number 2 [7].

nificant part of the financial benefit pie, but not all of it.

6. Conclusion

When analyzing the reference TTG and completed TTG for locally or remotely controlled lines, an increase in line throughput was found for remotely controlled lines. For a demonstrable assessment of the advantage of remote control, a proposed point mechanism was used, which is based on the priority of trains. Savings resulting from lower personnel requirements, which are reflected in lower labour costs, have also been demonstrated. These benefits of remote control have been proven. But it was necessary to evaluate the benefits. Based on these requirements, the mechanism of this evaluation of the advantages of remote control and point system was designed. Based on the proposed point system, individual types of management can be demonstrably evaluated. Furthermore, a method of creating type trains for the given edges of the selected track section was proposed. These methods of evaluating the benefits of running and creating type trains are designed to be applicable on any section of the chosen line. In the final evaluation, the railway transport management evaluation mechanism was applied. Through induction, it was confirmed that remote control would bring benefits in terms of more efficient TTG, savings of 44.63 % and also labor costs of 36.89 %. If we convert these results into absolute numbers, the annual savings on the selected section of the line amounts to more than CZK 11.3 millions.

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