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Research Article

Impact of Change of the Interlocking on the Acceleration of Railway Transport: A Case Study from the Podbrezová Railway Station

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Accelerating rail transport is a key factor in improving the quality of passenger and freight transport. The main research question of the article asks whether it is possible to increase the speed due to the change in the interlocking. The main research tool is a comparison of the interval of crossing before and after the reconstruction of the interlocking. As the entire research is carried out on a single-track line at the Podbrezová station, the interval of crossing is the most relevant indicator. An associated goal of the entire research is to point out a possible increase in the carrying out of station tracks and an overall improvement in the working conditions of operational staff (station inspectors and switchmen).

1. Introduction

Modernization of railway infrastructure is one of the key elements of higher safety and higher quality of transport processes. Despite its financial and economic demands, modernization at various levels is necessary especially when rail transport is to be competitive with other modes of transport. It is also one of the key ways to attract new passengers and customers to take advantage of this mode of transport.

Modernization of an interlocking is defined as the replacement or exchange of an old interlocking with a new one. In the conditions of the infrastructure manager in Slovakia (Railways of the Slovak Republic), it is most often the case of replacements of mechanical interlocking cabins. Electromechanical interlocking are placed with the possibility of centralized dispatching. In addition to the modernization itself, this process also hides various positive effects, among which we can include a lower need for operating personnel (no need for switches and signallers). There is also a presumption of an increase in the speed of trains when passing through a station or crossing (on a single-track line). Assuming that the speed increases, it is also assumed that the degree of occupancy of the station track will decrease, and thus the carrying out will increase.

The main aim of the articles is to find out whether the modernization of the interlocking will increase the speed and smoothness of railway transport during the interval of crossing. Since the entire research is set in the environment of the single-track line Banská Bystrica-Červená Skala, specifically to the station Podbrezová, this is the most common type of interval, which represents a bottleneck on this type of line. The examination procedure has two main parts:

(1) Creation of overrun interval technology on the mechanical interlocking cabin, which was the original, and subsequent creation of the technology of this interval on the all-electric interlocking apparatus, which is the current, new station interlocking

(2) Calculation of individual components of an interval of crossing based on the resulting durations of individual technologies

Another important aspect is the aspect of increasing the safety of operations staff (station inspector), which will also be pointed out in the article through advantages and disadvantages. However, this aspect will be further explored. If the speed and smoothness of railway transport on the railway line in question increase at the solved railway station, at the end of the article, the recommendation will continue with such modernization measures, despite the high investment and economic demands.

2. Literature Review

The relevant literature review will focus on different approaches to the modernization of railway infrastructure and the subsequent possible dispatch centralization. In many European countries, different approaches to modernization are applied. Dispatch centralization is their common denominator. The article [1] provides the first experience of the Portuguese railway network in the late 1990s. This is a modernization of station security equipment by ALCATEL. The installation results show long-term reliability. During that time, however, the level of development has shifted and is still moving by leaps and bounds.

Communication at different levels is important in dispatch centralization whether between the railway vehicle and the track, between the track and the interlocking system, as well as between the train drivers or between the station inspectors of the controlled areas. These schemes are discussed in the article [2], where the authors use simulation in MATLAB to model the ideal communication interface. This simulation in the conference paper can serve as a basis for building remote control centres in Romania. The communication level is also important for our research, as during the overall reconstruction of the interlocking, the block system is often changed. This change then also affects the communication between the station inspectors of neighbouring stations.

As the trend of remote control of rail transport is a trend of the last thirty years, the issue of safety is growing stronger. Article [3] deals with this very issue. In the environment of the Lithuanian Railways, where almost one hundred percent of lines are operated in this way, a safety system based on the prediction of possible adverse circumstances is being developed through this article.

In addition to an in-depth analysis of the buyer's financial capabilities, the selection of the interlocking is preceded by an in-depth analysis of its parameters. Article [4] analyses several security devices using their features and degree of reliability using FPGA technology. This research is beneficial for our article in the future when selecting other stations in which the reconstruction will be carried out.

A cross section of railway signalling equipment is given in article [5]. This conference paper is important for a general understanding of the past, present, and future direction in the development of interlocking systems. In our article, we also compare the now historical, mechanical interlocking cabin with an electrical signal box. Moreover, this article will serve us in the context of exchange in the changes of time.

A specific case is railway lines with simplified railway transport management. These are the lines and the associated railway stations, which show a low intensity of passenger and freight transport. The only controlling factor is the human factor, which has a high probability of failure. Article [6] deals with the possibilities of higher security on these lines. The research of our article can be applied to any station, and based on the current situation, we can prospectively calculate the acceleration of railway transport on such specific lines.

The level of the interlocking system also demonstrably affects the company's logistics and circulation processes. This impact is examined in article [7] and, as a result, shows favourable results and improvements, in the timeframe for the delivery of the goods to the final consumer. Although our research focuses primarily on passenger transport and the quality of mobility of the population, it is also possible to process the results obtained in freight transport.

The principles of operation of the selected type of all-electric interlocking apparatus are explained and described in the article [8, 9]. It thus completes the picture of the advantages and disadvantages of using all-electric interlocking apparatus. All the research studies are applied to the conditions of the South American and China rail networks.

Control mechanisms of the electrical signal box are the most important parts of the smooth running of rail transport. Therefore, they are designed, created, and prepared for models of the electrical signal box for a specific railway station. The security model for an electronic switchgear is discussed in a book chapter [10]. This model was tested on a specific type of electrical signal box, which was then installed at a specific railway station.

Prior to commissioning, each interlocking system must be tested, and its functionality is verified. It was no different in the case of the Podbrezová railway station. Because there are several types of authentications, the article [11] describes and examines several of them. This study applies research findings to selected railway stations. At the same time, there is an opportunity to try to apply the research findings from this article to the verification of security devices on the Railways of the Slovak Republic.

The specifics of interoperability are a very important part of the implementation of the new interlocking system. During the overall refurbishment of a railway station or track, care should be taken to implement a vehicle-track communication system and a driver-to-station inspector system. An example is an article [12] that addresses this issue in urban rail transport in the context of the use of the CBTC system.

The whole process of replacing different types of interlocking systems is accompanied by very strict safety requirements for operation and installation. Their summary provides an article [13] that applies those requirements to the Mohe railway station in China. Although the security requirements in Slovakia and China differ, it is good to compare the individual parameters and at least try to implement some of them.

As part of greater safety in interstation sections, new ways of block systems are constantly being developed. One of them is the Grobner-based model in the context of polynomial distribution, as presented in the article [14]. The block system also affects the duration of the operating crossing interval, so it is important to pay attention to this area as well.

The installation of a new interlocking is conditioned by changes in the elements in the track, especially switches. The article [15] focuses on the track, which can be modelled in the form of graph theory and its elements optimally searched using Dijkstra's algorithm.

An important element when using a certain type of interlocking system is its performance. This depends on several factors, such as the size of the track at the railway station or the number of trains passing through the railway station. In the article [16], the authors developed a system for comparing computer-controlled interlocking. Based on the input factors, the system automatically determines the most suitable type of interlocking for the station based on its performance. This avoids the extreme of undersizing or oversizing of the interlocking in the station.

The main purpose of replacing interlocking is to increase safety and reduce the impact of the human factor. In the article [17], the authors point out these two key factors in the development of a new interlocking system for Chinese railways.

3. Research Background

Podbrezová railway station is on the 55.139-kilometer railway line of the Banská Bystrica railway line. The railway line was put into operation on July 26, 1884, and the building of the current railway station was opened in 1912 [18]. For a better overview of readers, Figure 1 shows its location within Slovakia.

It is a railway station located on a single-track line. It is a railway station of the third category. Depending on the nature of the work, it is a mixed passenger and goods station, which is also an intermediate station. In terms of operation, it is a formation yard. The siding of the Železiarne Podbrezová company opens into the Podbrezová railway station [18]. It is one of the largest processors of metallurgical products in Slovakia.

The key element in every railway station is the track. The types and number of individual tracks are shown in Table 1.

The running tracks are used primarily for passenger and freight trains. Passenger trains are crossing on the running tracks with the platform. The service tracks are mainly used to build a load of freight trains, most often the load that came from the siding. Handling trains are formed on these tracks with the sufficient load. Stabling sidings are primarily used to bridge the time discrepancy between the loading and unloading of wagon consignments [30].

The number of trains is key for calculating carrying out. It is determined separately for even and odd directions, separately for passenger and freight trains, and separately for regular trains and trains as required. All these data are listed in Table 2.

At the Podbrezová railway station, a total of 12 passenger trains cross working days on the current train traffic diagram. From these, one pair is selected, which ran before the change and after the change (in different time positions, but with the same number) interlocking. The shortening interval of crossing is then calculated and demonstrated on this pair [31].

3.1. Operating Conditions at the Podbrezová Railway Station before the Change of the Interlocking. Until 2020, the Podbrezová railway station was equipped with a mechanical interlocking cabin. It is an interlocking of the 1st category. The light entry signals were independent of the position of the switches. Regarding the light entry signals (the station did not have leave signals or block station signals before the change of interlocking), the station inspector operated the buttons on the control board, which was in the railway office. He carried out the service only after the correct position of the train path, which was reported to him by the switches. The signal cabin was located on both station gridirons and was always occupied by one switchman. In both interstation sections (Podbrezová-Brezno and Podbrezová-Dubová) a telephone method of communication has been introduced [18].

For a more comprehensive understanding of the location of the elements described above necessary for the correct determination of the time of the operating crossing interval, Figure 2 shows the plan of the railway station Podbrezová, before its comprehensive reconstruction.

For a correct understanding of the individual time norms, which are in the calculation of the crossing operating interval, the technology of the work of the station inspector and switchmen in the construction of the entrance train path is presented in Figure 3 using the Gantt chart.

We can see from the graph that the process of preparing the entrance train path includes a total of 16 operations with a total duration of 6 minutes and 20 seconds. The longest action is the adjustment of the switches to the correct position [32]. This operation is performed by the switchman directly in the trackage and lasts one minute. The station inspector and switchmen on both station gridirons take part in the preparation of the entrance train path. The participation of both switches is necessary for the implementation of steps 3 (informing the switchmen about the approaching train) and 4 (confirmation of the switchmen's understanding of the given instruction). In the implementation of actions 5 (checking the warning of the train path by looking into the trackage) and 6 (notification of warning of the train path to the station inspector), only the participation of a switchman who is not actively involved in the preparation of the train path is required (the train does not pass through its area of responsibility).

Figure 4 again shows the procedure for preparing the departure train path using a Gantt chart.

The preparation of the departure train path consists of a total of twelve consecutive operations, in which the switchman and the station inspector also participate. The longest operation, which lasts one minute, is again the adjustment of the switches for the train path. The biggest change is that the participation of the second switchman in the preparation of the departure train path is no longer necessary. This also results in a shortening of the entire preparation process to 4 minutes and 25 seconds. This is a

Figure 1: Location of the railway station Podbrezová on the map of Slovakia [19].

reduction of almost two minutes compared to the preparation of the entrance train path [33].

An important part of the whole process of train arrival at the station and train departure is also the cancellation of the train path. The procedure of individual actions when cancelling a train path is always the same, whether it is an outgoing or incoming train. The sequence and duration of the individual operations are shown in Figure 5 using the Gantt chart.

The whole process of disturbance of the train path consists of four operations, the duration of which is a total of one minute and twenty-five seconds. The longest operation is to adjust the switches to the basic position according to the interlocking table. The interlocking table is placed in a key box at the signal cabin. Only the switchman participates in the process of cancelling the train path, without the presence of the station inspector.

In conclusion, it can be stated that in all three described station operations, the whole process is very lengthy. This is reflected in the smoothness and speed of passenger and freight trains that cross the oncoming train at the station. That is why the infrastructure manager is trying to eliminate these bottlenecks by modernizing the interlocking.

3.2. Operating Conditions at the Podbrezová Railway Station after the Change of the Interlocking. Comprehensive reconstruction of the trackage, including notification technique and interlocking, began in February 2019 and was completed in September 2020. The reconstruction was to eliminate operational deficiencies caused by the operation of obsolete or missing facilities. These were mainly [24–26]the following:

(1) Reconstruction of switches: originally stepped, hand-operated switches from the years 1971–1978, which already lacked spare parts, were replaced by remote-controlled points

(2) Trackage reconstruction: rail replacement and change of number and type of tracks

Table 1: Number and type of tracks at the Podbrezová railway station.

Type tracks	Number of tracks
Running tracks	5
Service tracks	3
Stabling sidings	5

(3) Installation of new entry, shunting and leave light signals with their separate light distance signal

(4) Construction of new platforms: replacement of the original narrow loose platforms with new wider concrete platforms

(5) Installation of a new audio-visual system to inform passengers of train arrivals and departures, including information on boarding and delays

(6) Installation of a new interlocking: replacement of the original mechanical interlocking cabin with a new all-electric interlocking apparatus

The price of the total reconstruction, which included the above six points, was calculated at € 8,750,000, including the preparation of project documentation. The contract based on the electronic auction was won by SIEMENS, with which the ŽSR infrastructure manager signed a contract.

The layout of the trackage has been changed on the trackage plan, new signal devices have been added, and both signal cabins have been cancelled. As a result, the jobs of switchmen were also cancelled. They were transferred to other railway stations, offered a different operating position, or an employment relationship was terminated with them. The management of railway transport was pushed into the railway office, fully within the competence of the station inspector.

The station inspector manages the railway transport using a new interlocking, an electrical signal box type SIMIS W. This interlocking is manufactured by SIEMENS. It is a fully electrical signal box with a contactless interface for external elements of the safe installation. All control, check, and logical functions of the safety installation are performed

Table 2: Number of trains running through station Podbrezová in train traffic diagram 2021/2022.

Train type in direction/regularity of trains	Passenger trains in the even direction	Freight trains in the even direction	Freight trains in the odd direction
Regular trains	17	1	
Train as needed	1	4	5

Figure 2: Railway station track plan before its comprehensive reconstruction.

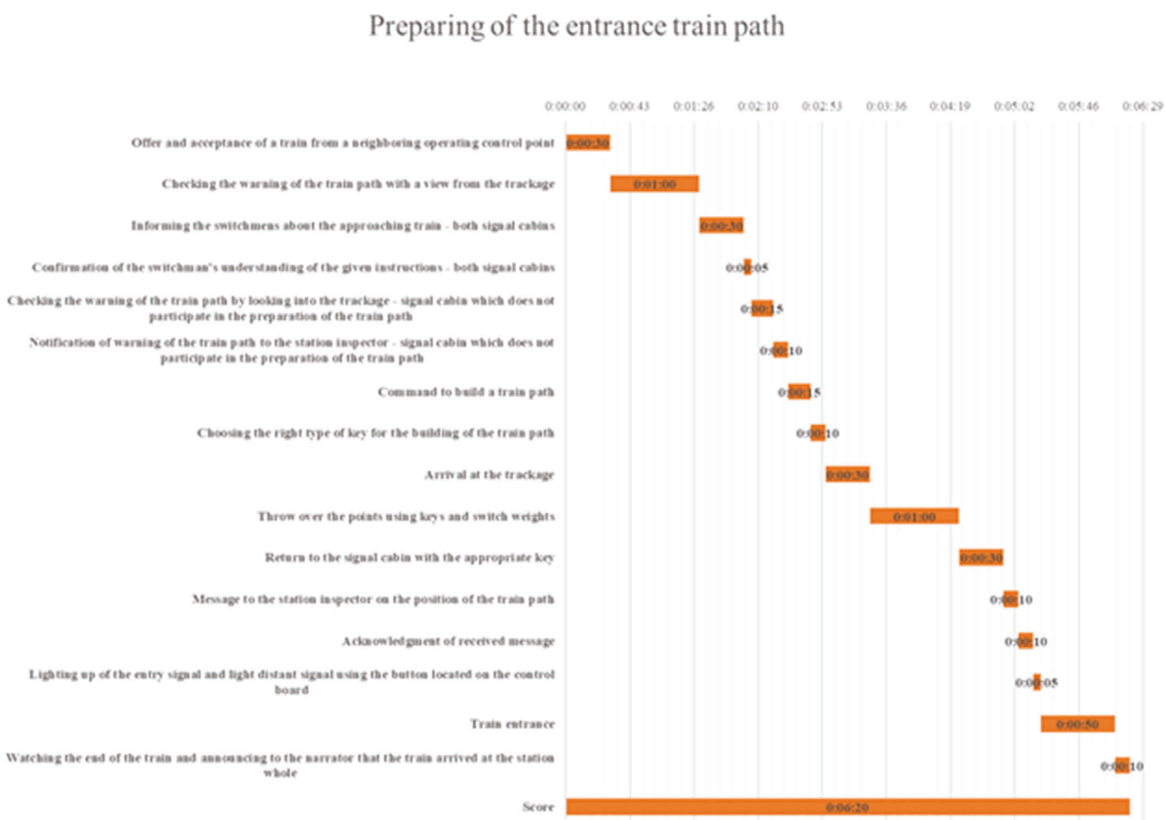

Figure 3: Preparing the entrance train path on the mechanical interlocking cabin.

by the computer-based on the requirements of the station inspector and the state of the technological unit. Electronic contactless interfaces are used as power signal switches for signalling lamps, LED lamps, and point machines or for sensing track circuit states, axle counting, auxiliary electromagnetic locks, and subsequent electronic or relay devices [27]. Figure 6 divides the components of which it is composed.

Using the input level with input computers is used to control and visually control the transport situation. In

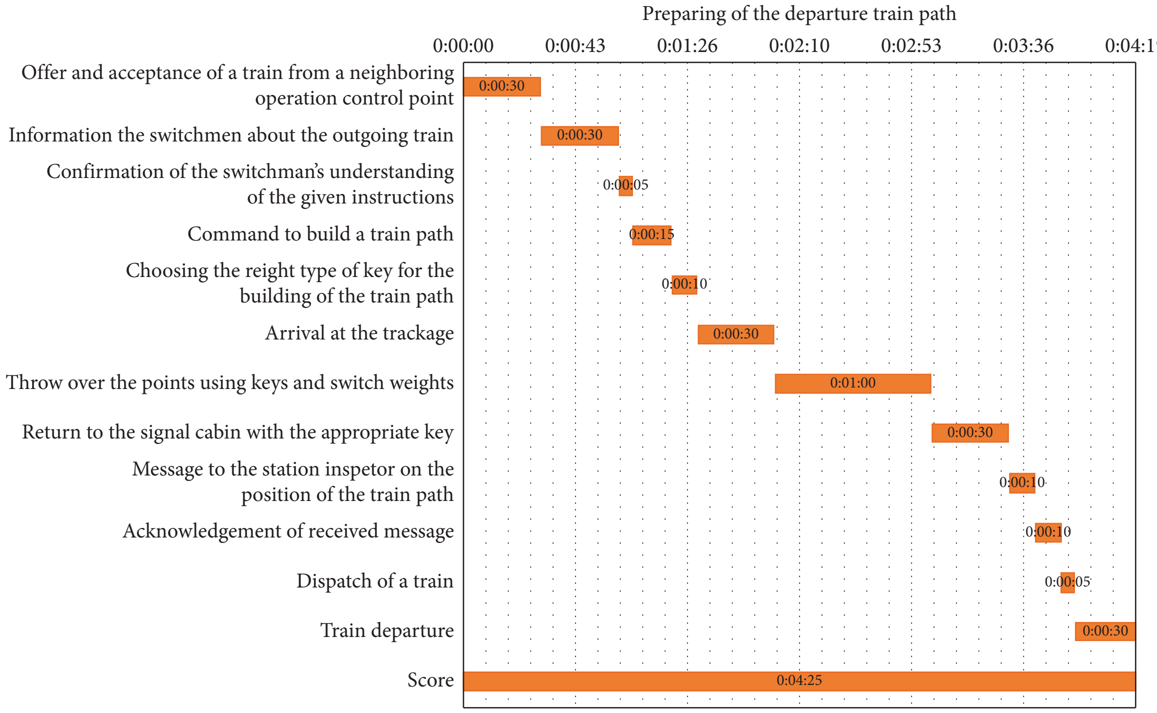

Figure 4: Preparing the departure train path on the mechanical interlocking cabin.

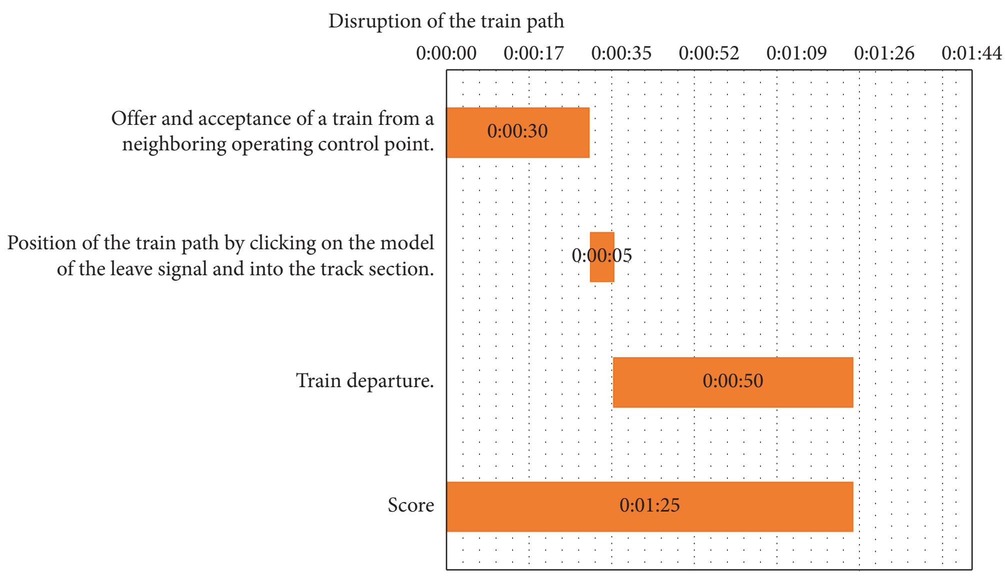

Figure 5: Train path disturbance on the mechanical interlocking cabin.

addition to performing partial algorithms, the implementation level with electronic interface panels also serves for contactless control and supervision of the external elements of the interlocking.

The change in the interlocking also represents a change in the preparation of train paths. Figure 7 shows the preparation of the entrance train using a Gantt chart.

The times achieved using the electronic signal box are incomparably shorter than the time of the mechanical interlocking cabin. The times achieved using the electronic signal box are incomparably shorter than the time of the mechanical interlocking cabin. The total preparation time for the entrance train path is at the level of one and a half minutes, including the train entrance and stop. At the same time, the station inspector no longer must go and physically check in front of the transport office whether the intended train path is clear. This is an important element in terms of the safety of the station inspector.

The preparation of the departure train path after the change of the interlocking is shown in Figure 8 by means of a Gantt chart.

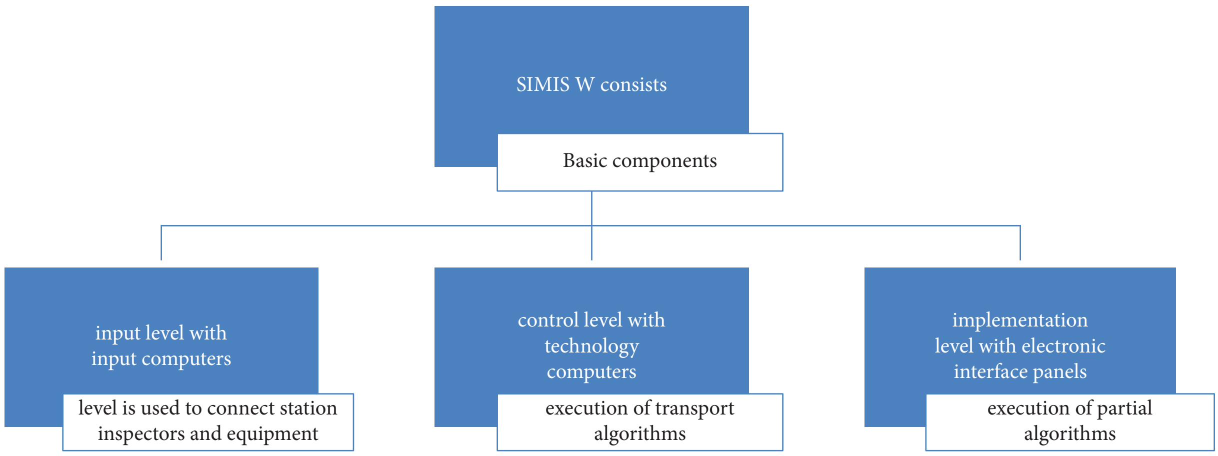

FIGURE 6: SIMIS *W* components.

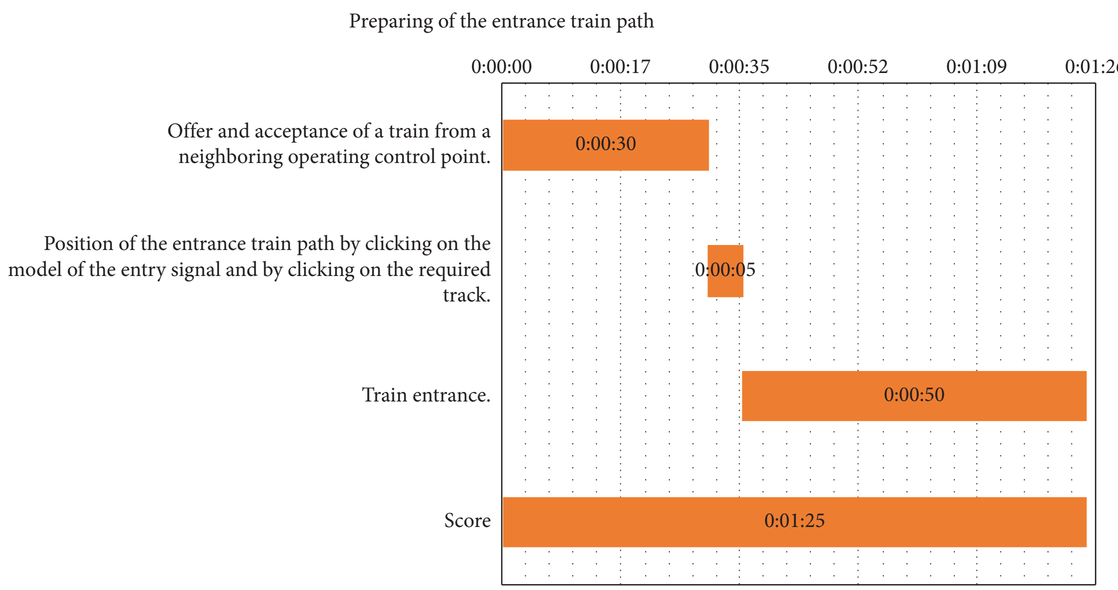

FIGURE 7: Preparing the entrance train path on the electronic signal box.

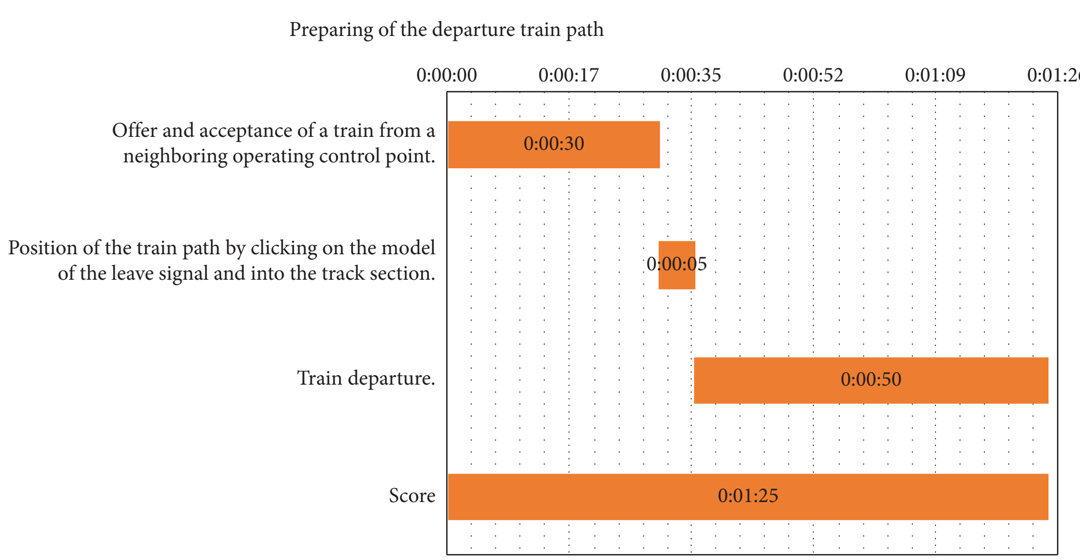

FIGURE 8: Preparing the departure train path on the electronic signal box.

The duration and number of operations are the same as in the preparation of the entrance train path. In this case, too, a comparison of the interlocking revealed a much higher speed and higher safety in the preparation of the departing train path.

Disturbance of the train path, which required special technology when using a mechanical interlocking cabin, is performed automatically when using an electronic signal box. The track on or from which the train path is built will turn green on the computer monitor. If the track is occupied by a train, it lights up red and the number of the train standing on it is added. If the train leaves the track and it remains empty, it will be greyed out on the computer monitor.

The comparisons made in this part of the article will serve as a basis for the calculations of the crossing operating interval in the practical part of the article.

3.3. Theoretical Background and Basic Equations Necessary for the Calculation of the Interval of Crossing. The operating interval is the shortest time required to complete the tasks prescribed for ensuring smooth train running and safety at the places decisive for its designation [28, 29]. This is, therefore, the shortest time between the continuous runs of two consecutive trains regarding impossible or illegal paths. It follows from this definition that this is the shortest time between the arrival, departure, or transition of the first train and the arrival, departure, or transition of the second train [20].

Station operating intervals are set for operating control points with track lead or for their separate parts, such as passenger, arrival, or departure groups of tracks [20]. The general equation expressing the resulting station operating interval is found in the following relation [29]:

$$\tau = t_{st} + t_d. \quad (1)$$

The time of station operations t_{st} includes the duration of all necessary actions associated with the security of the train running in the operating control point. These can be, for example, [20]as follows:

(i) Checking the warning of the train path: this action must be performed by the station inspector when preparing the train path, especially on the mechanical interlocking cabin or electromechanical signal box

(ii) Operation of various operating equipment in particular telephones, block systems, and interlocking

(iii) Walking at checking the warning of the train path

(iv) Necessary notices: they are most often used for telephone communication between two neighbouring operating control points or telephone communication to switches

(v) Dispatch of a train

What influences the component of station operations t_{st}, together with the facts affecting the component of dynamic operations td, can be found in Table 3.

The dynamic running component of a train may, in general, consist of sections of steady motion and sections of steady acceleration or deceleration to calculate operating intervals. The time of the dynamic component t_d expresses the travel time of the train required to cover the specified distance, which is related to the interval in question. These can be, for example, [20]as follows:

(i) Strength failure of the track

(ii) Arrival at the designated place

(iii) Departure from the designated place

What influences the component of station operations t_d, together with the facts affecting the component of dynamic operations t_{st}, can be found in Table 3.

If we apply the general calculation of station operating intervals to two trains, the equation is as follows [20]:

$$\tau = t_{st1} + t_{d1} + t_{st2} + t_{d2}. \quad (2)$$

Subscripts 1 and 2 express the relationship to the first or second train. The dynamic component is determined analytically by calculation. The calculation of the dynamic component can be divided into two basic parts [20]as follows:

(1) Calculation of partial driving time t

(2) Partial path calculation l

Table 4 shows the distribution of the partial time and the partial path with the corresponding calculations.

The equations given in Table 4 will be used in the calculation of the dynamic component for the second train within the interval of crossing. For a better idea, there is Figure 9 in which this interval is schematically shown.

The crossing interval (τ_k) is the shortest time between the moment of arrival of the first train and the moment of departure of the second train at the station, provided that the second train leaves for the same open line from which the first train arrived [20]. As the picture shows, we will call it τ_k and it is calculated only on single-track lines.

4. Interval of Crossing as a Tool for Assessing the Acceleration of Railway Transport due to the Comprehensive Reconstruction of the Railway Station Podbrezová

To calculate the interval of crossing, we selected two passenger trains that ran before and after the reconstruction of the railway station. On these two types of trains, the time savings that will result from changing the interlocking device will be demonstrated.

4.1. Interval of Crossing When Using a Mechanical Interlocking Cabin. The parameters required to calculate the interval of crossing are given in Table 5. The data will be the same in both calculation cases, except for the interlocking.

The decisive place for determining the operating interval is always only on the departure gridiron of the second departing train.

Table 3: Elements affecting the components of station (t_{st}) and dynamic (t_d) components of station operating intervals.

t_{st}	t_d
Kind of interlocking	Train length
Kind of notification device	Train speed
Way of operating points (moving parts of the switch)	Train weight
Kind of signals	Row of locomotives
Kind of block system	Gridiron distance
Construction arrangement of the railway station	Breaking-down distance
Articulation gridirons	Useful length of running track
Type of switches	Slope and direction conditions at railway station and near the railway station
Number of railway lines	Stopping or passing the train
Location of the railway office	
Number of operating staff	
Kind of operating staff	
Qualification of operating staff	
The method of determining the integrity of the train	
Local regulations	

Table 4: Calculation of parts of dynamic component variants.

Type of movement of the partial driving time	Type of movement of the partial path	Equation	Meaning of individual variables
Uniformly movement of the train		$t = l/v\,[\text{min}]$	t: train running time (min) l: the track the train has travelled (m) v: train speed for smooth motion relationships [km ∗ h − 1]
Uniformly accelerated or decelerated train movement		$t = v_2 - v_1/216 * a$ (min)	v_1: initial speed for equations of uniformly accelerated or decelerated motion [km ∗ h − 1] v_2: finite speed for equations of uniformly accelerated or decelerated motion [km ∗ h − 1] a: medium acceleration or medium braking deceleration [m ∗ s − 2]
	Uniform movement of the train	$l = v * t/0,06\,[m]$	
	Uniformly accelerated or decelerated train movement	$l = v_2^2 - v_1^2/25,92 * a\,[m]$	

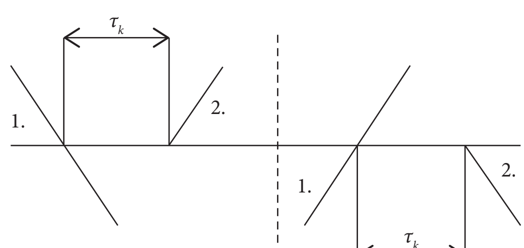

Figure 9: An interval of crossing τ_k.

The calculation is based on (2), so we first determine the actions and their durations that apply to the first train. All this is captured in Table 6.

It is clear from the table that the running time of the crossing interval starts by stopping the first train at the station. It also follows from the above that the longest time norm is the cancellation of the train path after the first train. However, the time norm of this operation cannot be determined exactly because it also depends on the speed and dexterity of the switchman.

Another component of the interval of crossing calculation is the station operations component t_{st2}, which applies to the second train. All operations, persons performing them, and time standards are listed in Table 7.

The station component of the interval t_{st2} is two minutes and ten seconds longer than the station component of the interval t_{st1}. This extension is mainly due to the preparation of the departure train path for the second train, which is performed by the switchman. The length of the time norm, in this case, depends on the position of the interlocking cabin (it is elevated, and the switchman must run down the stairs to get to the trackage) and the number of rebuilt points that interfere with the train path. At the same time, the table lacks the action of lighting the leave signal to a signal allowing driving, but the Podbrezová railway station was a railway station without leave signals. The fact that the train could safely leave for the interstation section was confirmed by the station inspector by dispatching the train.

Since the interval of crossing begins to run (imaginary stopwatch is switched on) by stopping the first train and the timing ends (imaginary stopwatch is switched off) by the departure (start-up) of the second train to the interstation section from which the first train arrived, dynamic components t_{d1} and t_{d2} are zero.

Table 5: Input data necessary for the calculation of the interval of crossing.

Example parameters	
Type of interlocking	Mechanical interlocking cabin
Type of blok system	1st category: telephone communication
Both train at the station stop	Passenger train (7222) from the direction of Brezno on track 2-1. Train Passenger train (7223) from the direction of Banská Bystrica on track 1-2. Train

Table 6: Calculation of station component t_{st1}.

Serial number	Operation	Implementing	Duration
1.	Return to the railway office	Station inspector	0, 20 min
2.	Train end message	Switchman and station inspector	0, 10 min
3.	Cancellation of a train path after the first train	Switchman	2, 05 min
4.	The advice of train arrival	Station inspectors both railway station	0, 20 min
	Σ		2, 55 min

Table 7: Calculation of station component t_{st2}.

Serial number	Operation	Implementing	Duration
1.	Offer and acceptance for the second train	Station inspectors both railway stations	0, 25 min
2.	Order for the construction of the departing train path for the second train	Switchman and station inspector	0, 20 min
3.	Adjustment of points (moving parts of the switch) for the departure of the second train	Switchman	73, 50 min
4.	Walking to the train and train dispatch	Station inspector, train master, and guard	0, 30 min
	Σ		5, 05 min

After substituting the individual values into (2), we get the resulting value of the interval of crossing is eight minutes. Since this is a whole value, we do not have to round it up to half a minute. Nowadays, this time is unacceptable and therefore ways are being sought to reduce it. One of them is the replacement of interlocking in the context of the overall reconstruction of the railway station.

4.2. Interval of Crossing When Using an Electronical Signal Box. After the replacement of the interlocking and after its successful connection, it was necessary to recalculate the station intervals. Table 8 shows the input data required to calculate the interval of crossing.

The only thing that has changed compared to Table 5 is the type of interlocking. The mechanical interlocking cabin replaced the electronic signal box.

The calculation is based on (2), so we first determine the actions and their durations that apply to the first train. All this is captured in Table 9 as t_{st1} operations with their time norms.

The first difference to note is the lower number of steps that must be taken for this station component of the operating interval that they have halved. The biggest difference is probably the duration of the station component t_{st1}, after the replacement of the station security device. It was shortened by more than half, specifically by two minutes and ten seconds. Furthermore, greater cooperation and greater automation between the station inspector and the electronic signal box can be seen here. Moreover, finally, we can see from the table that the function of the switchman is no longer mentioned there. Switchmen are no longer required for this type of interlocking. One switchman was left at the railway station, working a total of eight hours on weekdays. The others were reassigned to other railway stations, took a preparatory course for the station inspector, chose a different type of work, or left the railways.

Another component of the interval of crossing calculation is the station operations component t_{st2}, which applies to the second train. All operations, persons performing them, and time standards are listed in Table 10.

Here, too, the number of operations decreased by one compared to Table 7. The resulting time was reduced by three minutes and thirty-five seconds. Since during the reconstruction of the Podbrezová railway station, leave signals were added, which are on the running tracks, the station inspector is obliged to light them up during the construction of the train path. This is also an instruction for the accompanying crew (trainmaster and guard) that they can dispatch the train and an instruction for the driver that the train can leave. Thus, the dispatch of the train by the station inspector would no longer be necessary in this respect and he would only be able to monitor the departure of the train in front of the railway office, but even after the interlocking has changed, the station inspector still dispatches the trains.

In this case, when we add the station components of the interval of crossing, we get the number two minutes and

Table 8: Input data necessary for the calculation of the interval of crossing.

Example parameters	
Type of interlocking	Electronic signal box
Type of block system	1st category-telephone communication
Both train at the station stop	Passenger train (7222) from the direction of Brezno on track 2-1. Train Passenger train (7223) from the direction of Banská Bystrica on track 1-2. Train

Table 9: Calculation of station component t_{st1}.

Serial number	Operation	Implementing	Duration
1.	Return to the railway office and automatic cancellation of a train path after the first train	Station inspector and interlocking	0, 25 min
2.	The advice of train arrival	Station inspectors both railway stations	0, 20 min
	Σ		0, 45 min

Table 10: Calculation of station component t_{st2}.

Serial number	Operation	Implementing	Duration
1.	Offer and acceptance for the second train	Station inspectors both railway stations	0, 25 min
2.	Built of the train path for the 2nd departing train (including lighting of the leave signal at the signal allowing running)	Station inspector	0, 35 min
3.	Walking to the train and train dispatch	Station inspector, trainmaster, and guard	0, 30 min
	Σ		1, 30 min

fifteen seconds. However, this number should be rounded up to the next half minute, so it will be two minutes and thirty seconds after rounding.

5. Results

The results can be divided into two separate units. The first unit reflects a comparison of the two values of the interval of crossing before and after the reconstruction of the railway station Podbrezová. The second unit will focus on the advantages, disadvantages, and risks of working with a mechanical interlocking cabin, as well as on the advantages, disadvantages, and risks of working with an electronical signal box.

Figure 10 is a comparison of the interval of crossing (τ_k) duration. This comparison is based on a change in the interlocking. The data needed for comparison are based on the sums of the resulting values in Tables 6–10.

The result is not surprising. The crossing interval was shortened by more than five minutes, which will contribute to greater fluidity and accelerated rail transport. This acceleration will be reflected in the entire train route, from Brezno to Banská Bystrica. As the reconstruction was completed in September 2020, the acceleration of the trains is only incorporated in the train traffic diagram for 2020/2021. The transitional period could be considered as testing or trial. At the same time, it was possible to reduce train delays more effectively during this period, due to long downtimes at the Podbrezová railway station.

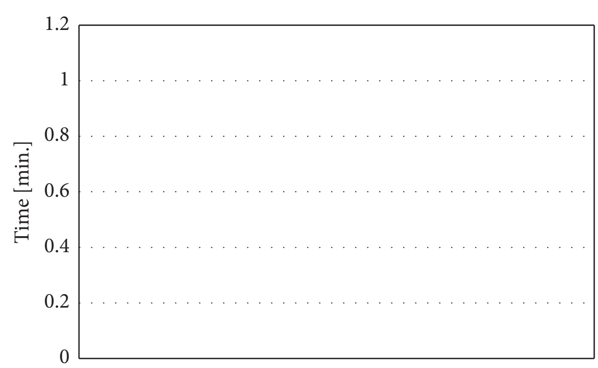

Figure 10: The resulting comparison of the crossing interval (τ_k).

Changing the interlocking brings advantages, disadvantages, and risks. The bottlenecks that arose and could not be removed when using the old interlocking were removed during the installation of the new, but others were created that did not exist when the old interlocking was used. Table 11 outlines the main advantages, disadvantages, and risks associated with the use of these two types of interlocking.

Based on the table, it is possible to state that any type of interlocking has its advantages, disadvantages, and risks of working with it. No matter how modern the interlocking is, the influence of the human factor on its operation is not negligible. It follows that it is not possible to prevent emergencies completely. Although with proper education and training, the occurrence of extraordinary events caused by the human factor can be eliminated to an increased extent.

Table 11: Main advantages, disadvantages, and risks associated with the use of interlocking.

Mechanical interlocking cabin			Electronical signal box		
Advantages	Disadvantages	Risks	Advantages	Disadvantages	Risks
Independence from electricity supply	Long interval of crossing	Possible failure of the human factor	Fully automatic operation	Dependence on electricity supply	High probability of falling into a stereotype
More employment	High staff costs	Possible injury to switchman and station inspectors at the necessary entrance to the trackage	Lower economic costs for employees due to the reduction of their number	Relatively frequent failure rate	High probability of human factor failure in electronic signal box failure
More jobs	Independence of signals at the position of switches	Insufficient security of the train and shunting path	Elimination of the need to enter the trackage	High acquisition costs	Higher sensitivity of the interlocking to external conditions

6. Discussion

If we look at the whole reconstruction process comprehensively, we will find that it seems unfinished. It is a fact that during the reconstruction of the Podbrezová railway station, the reconstruction of the block system was "forgotten." In both interstation sections (Podbrezová-Brezno and Podbrezová-Dubová), a telephone method of communication has been introduced. In addition to its obsolescence, this method is also dangerous because it depends only on the human factor (on the station inspectors of neighbouring stations). Therefore, the following questions are relevant to the discussion:

(1) What new type of block system would be most suitable for both interstation sections?
(2) How will the interval of crossing change after the elimination of the telephone method of communication in the interstation sections?
(3) Will it be necessary to implement a closure and introduce a replacement bus service during the installation of the new block system?
(4) By how much is it possible to assume an increase in the price for the reconstruction of the Podbrezová railway station when the block system is changed?

The results of the article [21], which would be interesting to apply to the conditions of the Railways of the Slovak Republic, can help with the answers to some questions. The Indian Railways also went in a similar way, where the main driving force for the creation of the article [22] was the need to increase the capacity of selected interstation sections.

Another element that is worth discussing is the staffing of the railway station by operational staff. As our article shows, after the change of the station security equipment, the required number of employees is lower. Even so, the function of a switchman at the Podbrezová railway station ceased to exist. Therefore, the following issues are relevant to the discussion:

(1) What is next for redundant switchmen?
(2) How much will the station's staffing costs be reduced?
(3) Will the safety of operation, despite the installation of an electrical signal box, not be endangered by the elimination of switch jobs?
(4) What could be the further use of the signal cabin?

An answer to some of the above questions could be provided by a conference paper [23] which deals with the issue of dispatching centralization in the context of the abolition of switchman jobs. There is generally very little relevant literature on the issue of railway switchman jobs.

The topics for discussion are based on other possibilities of research direction in this area. The authors strive to stimulate deeper research in this area, given its benefits not only for passengers and their safety but also for the competitiveness of the entire railway sector in relation to other modes of transport [34].

7. Conclusion

The aim of the paper was to compare the situation before the reconstruction of the interlocking and after the reconstruction of the interlocking based on the calculation of the interval of crossing, as a basic element of operation on a single-track line. This comparison served to confirm the hypothesis of whether such a change brought an increase in the smoothness and speed of railway transport at the Podbrezová railway station.

These results show that rail transport can be accelerated by more than 5 minutes. This acceleration can not only contribute to a reduction in travel time and thus to an increase in passengers on the route in question. As there is strong bus traffic between Brezno and Banská Bystrica, this improvement will also increase the competitive share of public passenger transport on the route in question.

At the same time, the authors point out the advantages, disadvantages, and risks arising from the replacement of the interlocking whether they concern operations or staff. Suggestions for further research are given in the discussion.

Data Availability

The results of the article are possible to verify directly in practice based on the operational processes of the station. The methodology is based on the DP1 infrastructure manager's regulation, which is available online at https://fpedas.uniza.sk/~gasparik/DP%201%20(10.12.2017).pdf.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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