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Improvement of the Last Mile-Specific Issues in Railway Freight Transport

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Abstract: The last mile is characterized as the last step of delivery to the customer from the logistics point of view. It is necessary to aim and fulfill all customers' needs mainly during the process of the last mile, because it is directly connected to them. Customer orientation can cause many complications that must be solved according to their will. This part of the supply chain is currently under pressure. Nowadays, trends have changed the last mile into a more ecological process mostly in the transport field. Railway transport is considered as an ecological transport mode therefore the last mile should be done by the railway transport. Preconditions for doing the last mile by the railway transport is the existence of siding (special purpose tracks) at the place of delivery. Our research focuses on minimizing the negative impacts of the last mile to customers in the context of using sidings. This research is based on the real conditions of the Slovak rail network, and on consultation with some experts from freight transport companies.

Keywords: transport technology; transport time; siding; last mile

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1. Introduction

Fluency of all flows is a very important transport factor nowadays with a significant impact on the delivery process. Another key factor is time, which can be divided into transport time and delivery time, which is not the same. Time is the key determinant of freight transport. The importance of this determinant is based on the whole transport process and its characteristics. From an overall evaluation point of view, time and fluency are factors with a significant impact to the quality of transport. This consideration classifies time and fluency into qualitative factors of transport. Potential customers decide usually according qualitative factors, so the time of transport is very important. It is necessary to satisfy all customers' needs, such as decreasing the transport time.

Time is an important value nowadays because it is necessary to meet all deadlines. In the transport field, current trends lead to a decrease in transport time, but the overall quality of transport must be high. This is the main task of all transport companies because their ratings are based mostly on time factors and quality aspects. There are many ways and methods to decrease transport time and increase the quality of transport. Doing the last mile by the same transport company may have a disadvantage, such as downtimes in those railway stations, where the railways are connected to private railways or sidings. The purpose of this research is to describe possibilities of changing the operation technology with a positive impact to the time factor. An application of the proposal is shown on the international transport of malt on the route from Tychy (Poland) to the Lycos siding in Trnava (Slovakia). The proposed technology was analyzed and is shown through illustrative graphics, such as Gantt diagrams. The main result is the improvement of the entire transport process quality, which leads to customer satisfaction.

Our research focuses on the context of methods for improving the overall quality of transport and increasing the level of customer satisfaction. This can be done by some methods of logistics. Customers can choose the transport company in the current liberalized transport market. This situation has some counterproductive aspects, such as each transport can be done by another transport company. This aspect directly influences the time of the transport because poor cooperation between transport companies will increase the transport time. The aim of this research is to propose a siding operation by the same transport company, which can be used for transport. The result of this proposal is to have satisfied customers because transport times will decrease.

The main problems with transport and delivery times are downtimes, which can be caused by many reasons at all points of the transport process. These reasons must be deeply analyzed, because only correct analysis can exactly describe all the problems and their practical solutions. Downtimes must be always minimized. Downtimes in railway stations, where sidings are connected to the rail network, can be minimized by selected methods. One problem causing downtimes is due to the lack of free tracks in the railway station. The purpose of the research is to change transport technology and transport times. A case study was applied to the international transport of malt on the route from Tychy (Poland) to the Lycos Trnava siding (Slovakia). The main aim was to plan the transport so that it would not have any negative impact to operations on the rail network or in railway stations. An example is described using the railway station of Trnava (Slovakia). Delivery must be efficient from the time point of view. Gantt diagrams are used for graphical representation of the transport technology. The main result is to create a new proposal for the distribution and parking of railway vehicles that are used for this transport. The purpose is to minimize negative impacts to railway operations at the Trnava railway station and transfer waiting railway vehicles to other railway stations.

The transport fluency factor is also affected by the length of siding tracks. Sometimes the train is longer than the length of the siding tracks; this problem is described in the research. When the train is longer than the siding tracks, some wagons must be left in those railway stations, where the siding is connected to the rail network. The Lycos siding in Trnava is connected to the rail network at Trnava freight station. During the loading process, half of the wagons are left there, and they take up free tracks for other activities at the station. It is necessary to propose a new operation technology that will minimize negative impacts of wagons that are waiting at the railway station. According the network statement, the usage of railway infrastructure is evaluated. This is one of the highest costs of transport companies.

2. Overview of the Similar Research

In reference [1], authors deal with railway freight transport planning between sea and river ports. They use simulation and optimization methods to plan freight train routes in a way that other train routes will be not influenced at all. They analyze the railway line capacity in terms of train delays, and they evaluate those data statistically. Railway line capacity, as well as railway station capacity, is a very important factor in this research from a planning point of view. The capacity of each track must be planned correctly, and every siding operation too.

Reference [2] focuses on planning according to ecological aspects. These aspects are very important nowadays, because people realize all the negative effects of climate change, so a great emphasis is there. Transport price is another key factor, which directly connects transport companies to their customers. It can be calculated with external environmental costs included. All negative environmental impacts should be incorporated and will affect transport technology.

Authors in the reference [3] are concerned with issues of changing the transport mode from roads to railways in Japan. They describe restructuring processes, because it is a method to improve the position of railways in the transport market. These issues also exist in Slovakia, where the modal split of freight transport is only 30% for railways. The most used transport mode is road transport, which is more flexible and cheaper than railway transport. On the other hand, the majority of main roads are overcrowded and there are significant congestions.

In ref [4], freight trains are dispatched by the Internet of things. Advantages of this method are the exact location of the shipment for the dispatcher of the transport company and for the customer too. It allows flexible reactions to potential problems. It is appropriate to use these systems also for siding operations.

Information databases of railway transport operations, as well as all related issues and documents, have a significant impact to the overall quality of transportation processes. This is stated in ref [5], which presents wide research that is based on data from 3000 trains in a 6-month period. Automatic data cleaning provides relevant information for dispatchers, which is very useful for strategic operation management of transport companies.

It is also important to prioritize freight transport on the line. That is why freight corridors are being built, the main aim of which is to speed up freight transport. This article deals with the method of prioritization [6], which sets priorities for individual trains.

For trains running on certain days of the week, it is important that the routes in the timetable are set regarding other rail transport. This will prioritize direct trains whose shipments usually require a considerable amount of importance. This problem is discussed in the context of seamless transport in [7].

Another important aspect of the course of rail transport is the capacity of the nodes. This is discussed in article [8], which examines the common and different characteristics of the methodologies used.

Railway infrastructure and its quality also play a key role in transport. What if the quality is getting worse and worse? An answer to this question is offered by article [9], which is set in the passenger transport environment. However, the authors believe that its conclusions can be used in the environment of rail freight transport after slight adjustments to the factors.

For rail freight to develop and meet the transport needs of customers, an even distribution of performance is needed. This could be achieved through equal investment. The construction of road bypasses and new roads that prevent the formation of significant congestion is best described in article [10]. Investment and construction of rail infrastructure for rail freight should also be a priority.

Sufficient capacity of railway infrastructure is one of the main preconditions for fast transport. At the same time, it increases the probability of the delivery of goods on time. Various simulation tools are used to determine capacity. In [11,12] the broad-spectrum simulation tool OpenTrack was used.

The technologies presented in this article can also be used in article [13]. The article discusses the change of siding technology for a fossil fuel power plant using a new reloading system of Innofreight containers. This is a modern system for transporting thermal coal in special transport units—Innofreight containers. The assessment of the recent technology considers not only technical, but above all technological and economic changes and benefits. There was an analysis of the current situation and it was decided to introduce the recent technology of the Innofreight system.

As safety is a principal issue in all transport, it is necessary to address it at least on a secondary basis. We can take as a model [14], which deals with this issue in a specific example.

Customer decisions between modes of transport are also influenced by the costs of carriers. The price for transport is then derived from this. Case study [15] focused on such a comparison in the Czech Republic, specifically on a selected route in the Pardubice region.

Various mathematical models can be used to help create the optimal route (as an end point, including sidings). The transport problem and its modifications are suitable for the distribution problem, as presented in article [16].

The availability of rail transport is overwhelmingly addressed from the point of view of passenger transport. This indicator is key to setting the competitive potential for a given session, as discussed in article [17]. Accessibility also has a place in rail freight transport. For example, if the siding is not available for trucks or does not have a loading ramp, it is a significant complication for customers; that is why they prefer to use road transport and what greatly reduces the competitive potential of rail freight.

In public passenger transport, for example, a methodology is proposed for accessible transport that considers various criteria. As in article [18], it is also worth thinking about dealing with such issues in freight transport and make the freight transport also accessible to customers everywhere.

Before starting transport itself, it is also important to decide to transport by rail. In articles [19,20], the authors therefore deal with the possibility of transporting a specific raw material by different modes of transport.

3. Materials and Methods

International transport of malt is done on the route from siding Lycos via Trnava freight station, Leopoldov, Čadca, borders Slovakia/Czechia, Návsí, Petrovice u Karviné, borders Czechia/Poland, Zebrzydowice to the final station Tychy. The transport operates on selected days according the transport plan, which is created by the supplier and the customer loading site. In this case, the supplier was the malting plant Lycos and their customer was Tyskie Browary Ksiažece (a brewery). The transport companies that are provide this transport are shown in Table 1.

Table 1. Transport companies overview.

Transport Company	Country
Prvá Slovenská Železničná, a.s.	Slovakia Czechia
Polskie Koleje Pańśtwowe Cargo, s.a.	Poland

The transport in done using Uagps wagons. This type of wagon has specialized construction that is suitable for this transport. In Table 2, there is basic information about this type of wagon.

Table 2. Basic information about Uagps wagons [6].

Length (m)	Wagon Weight (t)	Cargo Weight (t)	Bulk Capacity (m³)	Purpose
14.84	23.50	57.70	75	Cereals transport, spilling device

In Figure 1, there is the scheme of this type of wagon with basic parameters [21,22].

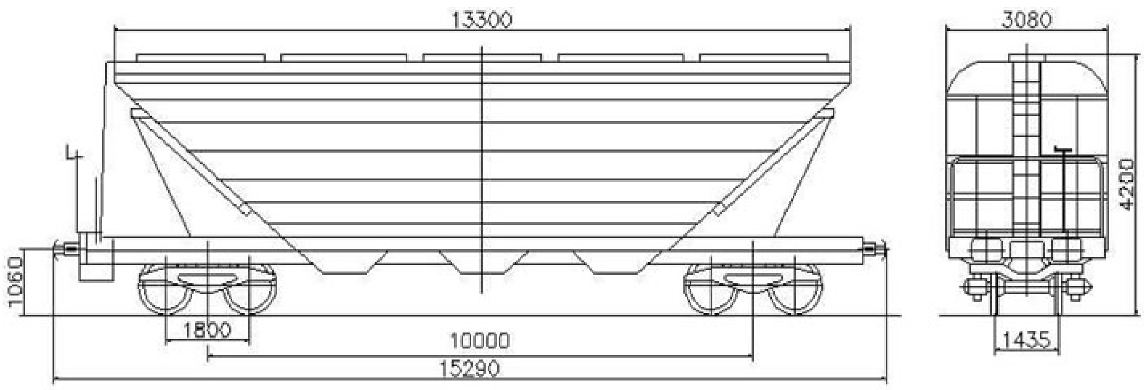

Figure 1. Uagps wagon with basic parameters in millimeters [7]. ,

The Siding operation of the siding at Lycos is done by the transport company PKP Cargo International (formerly Advanced World Transport). The siding operation at the siding in Poland is done by the transport company PKP Cargo, s.a. (the same transport company that is doing the transport on the Polish section of the route). The train must be subscribed to all transport companies at least 24 h before departure from Trnava. It is necessary to negotiate the exact time the train crosses state borders. Taking over the train between the transport companies is done at the border station Petrovice u Karviné (Czechia). In Table 3, there are basic parameters of the transport, which can be different according to the quantity of the goods. These values are used only as an example.

Table 3. Basic parameters of the train [23].

Number of wagons	18
Wagon type	Uagps
Train length	285.6 m
Empty wagons weight	410.4 t
Loaded wagons weight	795.1 t

From an efficiency point of view, it is very important to take into account the locomotive circulation and wagon circulation. PSŽ transport company uses ad-hoc locomotives according to infrastructure parameters (traction system, weight norms, fees for using diesel locomotives, etc.). Wagon circulation is shown in Figure 2.

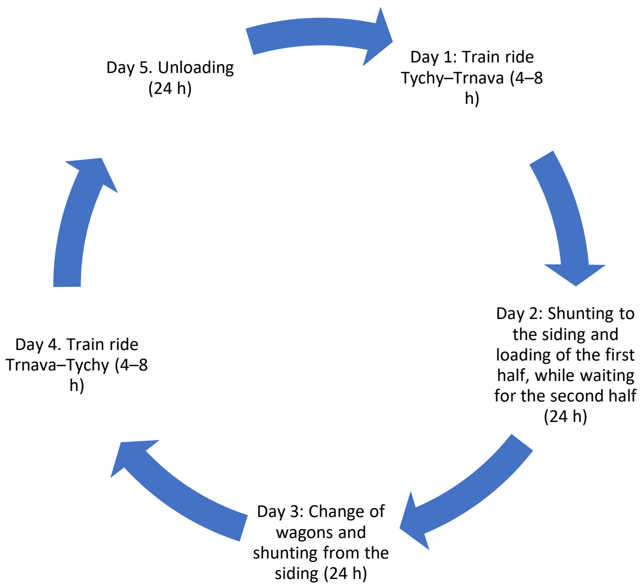

Figure 2. Wagon circulation on the route Tychy–Trnava and return.

The durations of the train rides are different, and depend on the current situation and unpredictable conditions. These conditions are stochastic because in the train there can also be other wagons from other transports, that have a similar route. As seen in Table 4, the circulation lasts five working days. During weekends and public holidays, loading and unloading processes are not done.

Table 4. Calculation of railway infrastructure fee [12].

Fee Part	Calculation
U_1	distance × rate
U_2	distance × rate
U_3	(gross tons × distance × rate) × 10^{-3}
U_4	(gross tons × distance × rate) × 10^{-3}
U_{SZ3}	number of stops × rate according to category
U_{SZ4}	rate for 24 h × number of wagons

The main problem of the last mile in the case study is the length of siding tracks. There is only one track, 150 m long. This is the reason why the train must be divided into two halves. Each half of the train is 143 m long. During the loading process, one half of the train is on the siding, while the other half of the train must stay somewhere. The loading process of malt lasts 24 h. In Figure 3, there is a simple Lycos siding scheme.

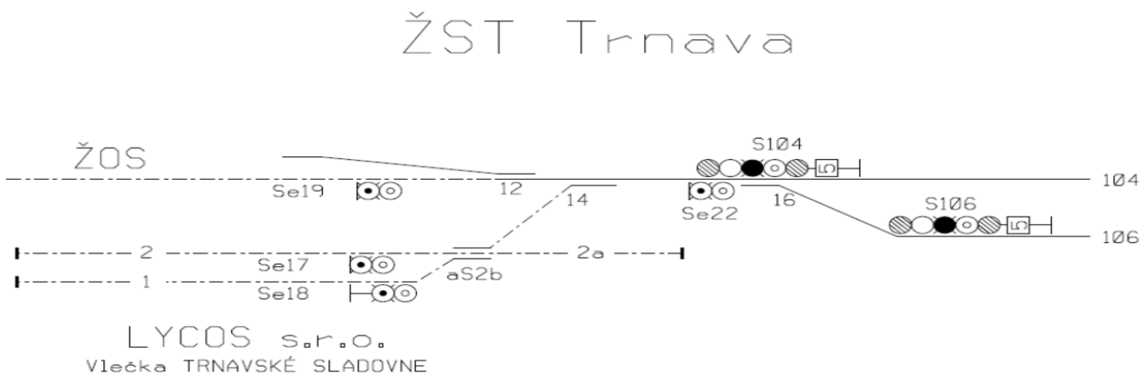

Figure 3. Scheme of the siding LYCOS [8].

It can be seen in Figure 1 that there are two tracks of Lycos siding. Track no. 1 is for the loading of malt, while the track no. 2 is for locomotives. There is not a hopper on this track to load freight wagons from above.

The railway station in Trnava is characterized as an important transport hub. It is divided into passenger and freight parts. There are railway lines to Bratislava (the capital city of Slovakia), Zilina (regional center in northern Slovakia with connections to Czechia and Poland), Kuty (border station of Czechia), and Sered (town in western Slovakia). The railway station in Trnava is powered with AC 25 kV 50 Hz. In Figure 4 there are different numbers of tracks in the station according their purpose. Valuable information for the case study is how many tracks could be used for the half of the train that is waiting for loading.

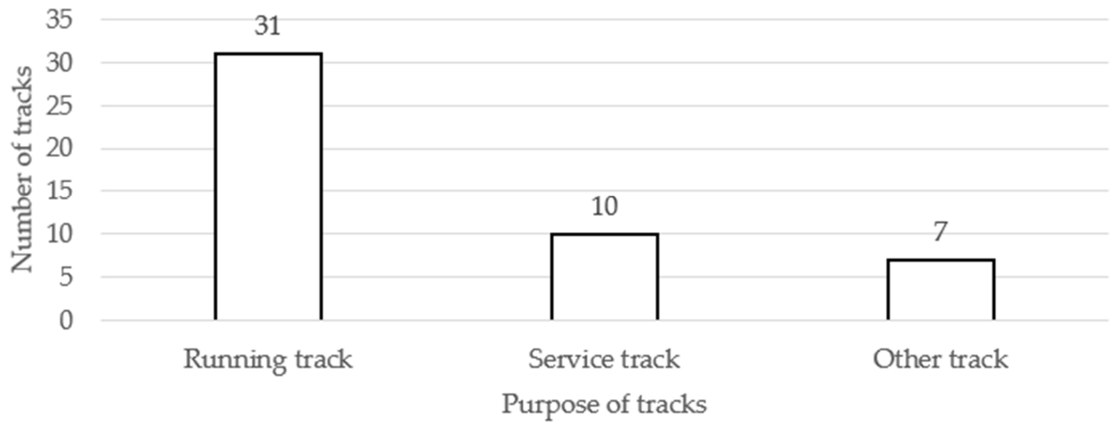

Figure 4. Number and purpose of tracks in the railway station in Trnava [24].

There are 39 tracks that could be used for parking. Half of the train could wait on one of the running or service tracks, except for two main tracks that must be free for passing trains. Despite many tracks at the Trnava railway station, there are often problems with the capacity. The majority of tracks are used by the company PSA Peugeot Citroen, which produces and transports automotive supplies. The unstable automotive market causes downtimes, therefore many trains wait in the railway station. Figure 5 shows the number of trains that are going to the siding of PSA Peugeot Citroen and then waiting at the Trnava railway station.

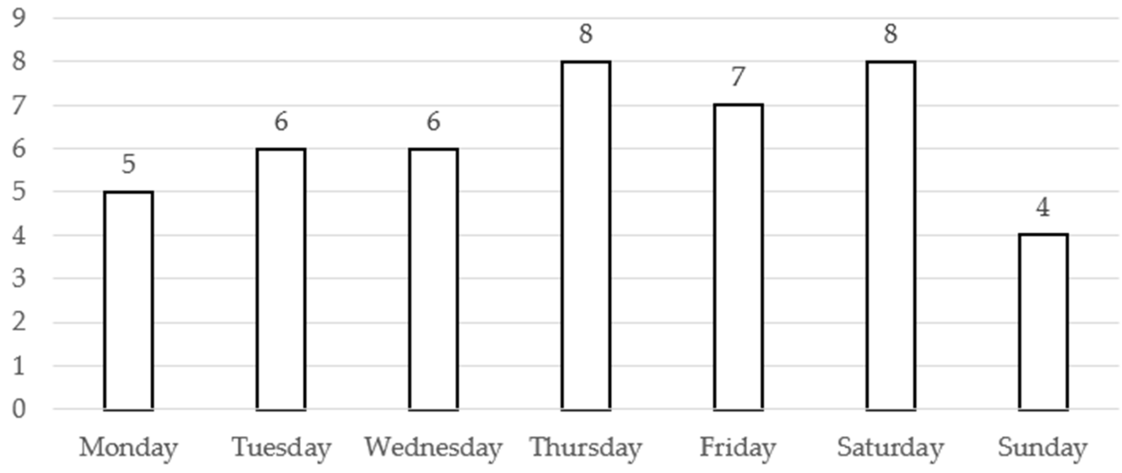

Figure 5. Number of automotive trains at the Trnava railway station over a week [25].

The highest number of trains are waiting at the Trnava railway station on Thursday and Saturday, while the least number of trains are waiting there on Sunday. Instead of automotive freight trains, there are also some waiting passenger trains of the Slovakia national transport company, ZSSK. Passenger trains wait there mostly during the night and parts of the day when demand is lower.

The Sereď railway station is situated on the railway crossing because there are railway lines to Trnava, Leopoldov, and Galanta. This station is smaller than the Trnava railway station from an operation point of view. The Sereď railway station is powered with AC 25 kV 50 Hz. In Figure 6, there are station tracks counted according their purpose.

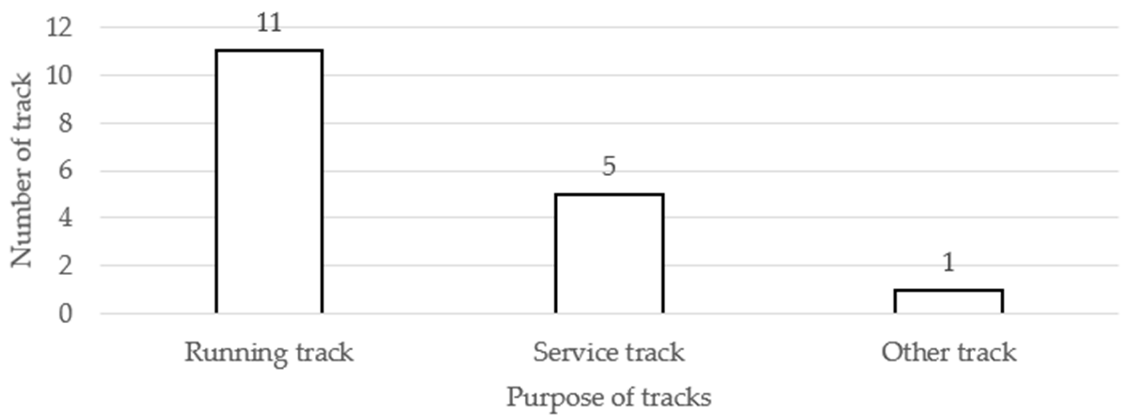

Figure 6. Number and purpose of tracks in the Sereď railway station [26].

There are two sidings that are connected to the Sereď railway station. One of these sidings is for the local sugar factory, and during the sugar beet season, there is regular operation of freight trains. The Sereď railway station is mostly a transit station from a freight transport point of view. It is not guaranteed that there will be free track for a waiting train, but the operation intensity is much lower there than the operation intensity at the Trnava railway station. Due to this reason, the probability of a free track for a waiting train is higher at the Sereď railway station.

From a case study point of view, the Sereď railway station is the best choice for the waiting of the half train while the other half of the train is loaded on the Lycos siding in the Trnava railway station. The Sereď railway station is only 15 km away from the Trnava railway station.

In Slovakia, railway infrastructure fees are dependent on these factors [27]:

- Railway line category

- Route type—ad-hoc or regular
- Where the train stops
- Train weight
- Load weight
- Locomotive type and traction
- Distance

Railway infrastructure fees in Slovakia consist of those parts, which are shown in the Figure 7.

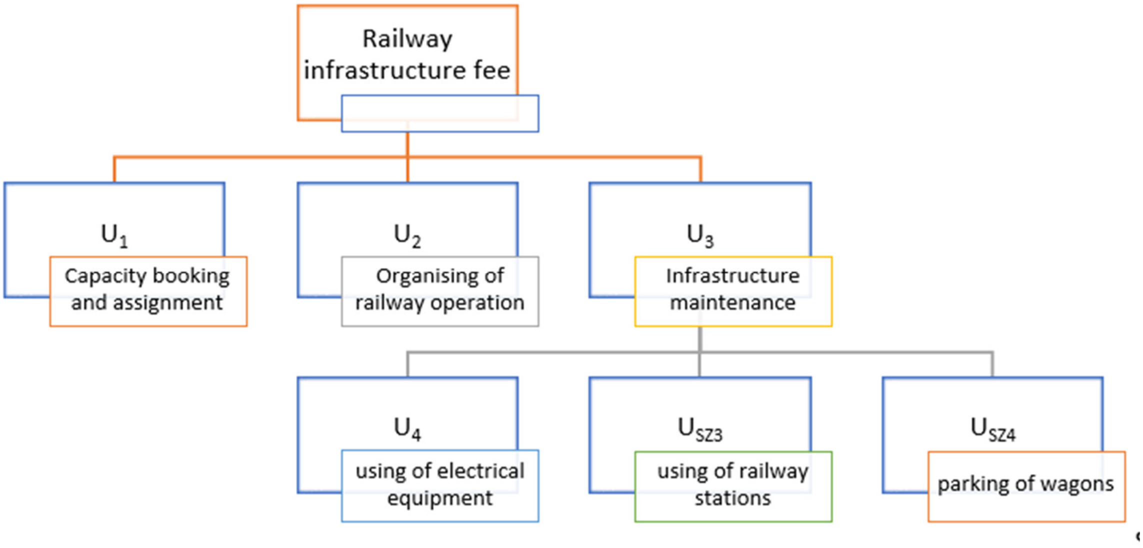

Figure 7. Parts of the railway infrastructure fee [27].

The calculation of railway infrastructure fees according their parts is shown in Table 4. The calculation for the case study is done in the Section I.

If some part of the train is transferred from the Trnava railway station to the Sereď railway station, every part of the railway infrastructure fee would be calculated. If some part of the train parks in the Trnava railway station, only part U_{SZ4} would be calculated.

The impact to the entire quality is shown through the models of Liljander and Strandvik that are connected to the multicriteria method and model of Lynn Schostack. Use of these models is appropriate for the subjective evaluation of transport processes. Function of this method is based on importance scale settings for selected criteria of quality and the level of precepted quality from the customer point of view. Selected criteria of quality (such as delivery time, siding track length, information about transport, etc.) are placed into quadrants according to the importance scale and level of perceived quality, which is directly connected to customer satisfaction. The ratio of customer satisfaction with each criterion is shown in those quadrants [28]. This quality evaluation is shown in Figure 8.

Figure 8. Evaluation of transport quality [28].

A case study was done according to the last mile delivery and customer satisfaction with this process. The customer was the Trnava malt factory. In the calculation of the entire transport quality, there were these parameters [28]:

- Importance rate—scale from 1 to 5,
- Level of perceived quality—half of the importance rate value,
- Ideal ratio of satisfaction (maximum quality)—value of importance rate multiplied with maximum level of perceived quality,
- Real ratio of satisfaction (perceived quality)—value of importance rate multiplied with real level of perceived quality.

The resultant value of the entire transport quality was determined according to Equation (1). This value must be multiplied by 100 because the final number is in a percentage [28].

$$Entire\ transport\ quality = \frac{Real\ ratio\ of\ satisfaction}{Ideal\ ratio\ of\ satisfaction} \tag{1}$$

In the results of this research, there are calculations for the entire transport quality of the transport from the case study. From this calculation, real satisfaction of the customer is proven [29,30].

4. Results

Results of this research are aimed to compare the current conditions with the proposed changes to transport technology in the case study. The train is currently parking at the Trnava railway station and the proposal is to park the train at the Sereď railway station. The comparison was done specifically for technological operations and the railway infrastructure fee.

The simplest and cheapest solution is to park half of the train at the Trnava freight station. If a dispatcher allows it, wagons can be parked on electric tracks because this transport is commonly done by electric locomotive. Figure 9 is a technological diagram that shows procedures and their duration after the empty train arrives. Half of the train is going to the siding for loading. The duration of each procedure is valid only in ideal conditions because they are directly dependent on many internal and external factors and aspects.

No.	Action	Who	Duration
1.	Train route preparation and train arrival	dispatcher + driver PSŽ	5 min.
2.	Locomotive unyoking	driver PSŽ	2 min.
3.	Assurement against the movement	driver PSŽ	7 min.
4.	Separation of the half of the train	driver PSŽ	15 min.
5.	Train route preparation and locomotive departure	dispatcher + driver PSŽ	1 min.
6.	Yoking of the first half	driver PKPCI	2 min.
7.	Entire breaking test	driver PKPCI	5 min.
8.	Train route preparation from station to siding	dispatcher	0.5 min.
9.	Shunting from station to siding	driver PKPCI	4 min.
10.	Locomotive unyoking	driver PKPCI	2 min.
11.	Train route preparation from siding to station	dispatcher	0.5 min.
12.	Shunting of the locomotive from siding to station	driver PKPCI	4 min.
Overall: 48 min.			

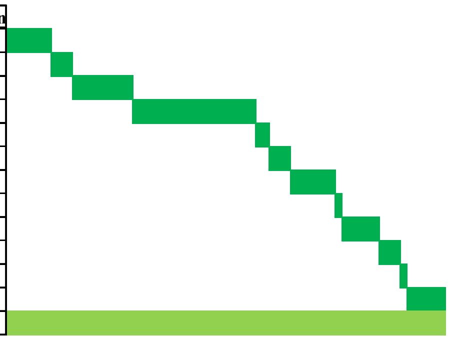

Figure 9. Technology for the arriving train.

Before this technology there is an order for the train route and an order for shunting, which is provided by PKPCI. Figure 10 shows the operation of changing the empty half of the train with the loaded half of the train. Before this operation, there is a PSŽ dispatcher's request for the changing of the halves. This is done by PKPCI.

No.	Action	Who	Duration
1.	Train route preparation from station to siding	dispatcher	0.5 min.
2.	Shunting of the locomotive from station to siding	driver PKPCI	4 min.
3.	Yoking of wagons	driver PKPCI	2 min.
4.	Entire breaking test	driver PKPCI	5 min.
5.	Train route preparation from siding to station	dispatcher	0.5 min.
6.	Shunting of the first half of the train from siding to station	driver PKPCI	4 min.
7.	Locomotive unyoking	driver PKPCI	2 min.
8.	Shunting in the station	driver PKPCI	5 min.
9.	Yoking of the second half of the train	driver PKPCI	2 min.
10.	Entire breaking test	driver PKPCI	5 min.
11.	Train route preparation from station to siding	dispatcher	0.5 min.
12.	Shunting of the second half of the train from station to siding	driver PKPCI	4 min.
13.	Locomotive unyoking	driver PKPCI	2 min.
14.	Train route preparation from siding to station	dispatcher	0.5 min.
15.	Shunting of the locomotive from siding to station	driver PKPCI	4 min.
Overall: 41 min.			

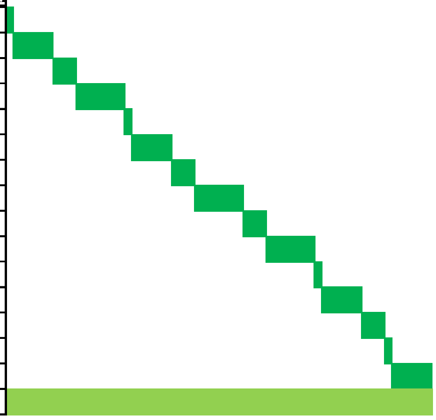

Figure 10. Technology of the train halves changing.

After the exchange of those halves, the second half of the train is loaded. This loading process also lasts 24 h. Later, the Lycos company produces the necessary documents for the transport (bill, wagon register, etc.) and the transport company PSŽ announces that the loading process has ended. All documents are sent from Lycos PSŽ. Then the PSŽ dispatcher sends an e-mail to the transport company PKPCI with a request for shunting from the siding to the railway station, where both halves will be connected to one train. Figure 11 shows the operation of shunting the second half of the train from the siding to the railway station, connecting both halves into one train, and the train departure.

No.	Action	Who	Duration
1.	Locomotive route preparation from station to siding	dispatcher	0.5 min.
2.	Shunting of the locomotive from station to siding	driver PKPCI	4 min.
3.	Yoking of wagons	driver PKPCI	2 min.
4.	Entire breaking test	driver PKPCI	5 min.
5.	Train route preparation from siding to station	dispatcher	0.5 min.
6.	Shunting from siding to station	driver PKPCI	4 min.
7.	Locomotive unyoking	driver PKPCI	2 min.
8.	Locomotive route preparation and PSŽ locomotive arrival	dispatcher + driver PSŽ	5 min.
9.	Connecting of wagons	technician PSŽ	5 min.
10.	Technival revision	technician PSŽ	60 min.
11.	Locomotive yoking	technician PSŽ	2 min.
12.	Entire breaking test	technician PSŽ + driver PSŽ	5 min.
13.	Train route preparation and train departure	dispatcher + driver PSŽ	2 min.
Overall: 97 min.			

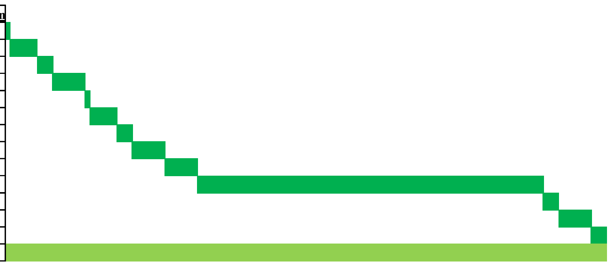

Figure 11. Technology of loaded train departure.

The PSŽ dispatcher tells the technician and driver about the duration of each operation action according to the time plan. The PSŽ manager plans the circulation of the locomotives and wagons. Figure 12 shows the comparison of operations from a time point of view.

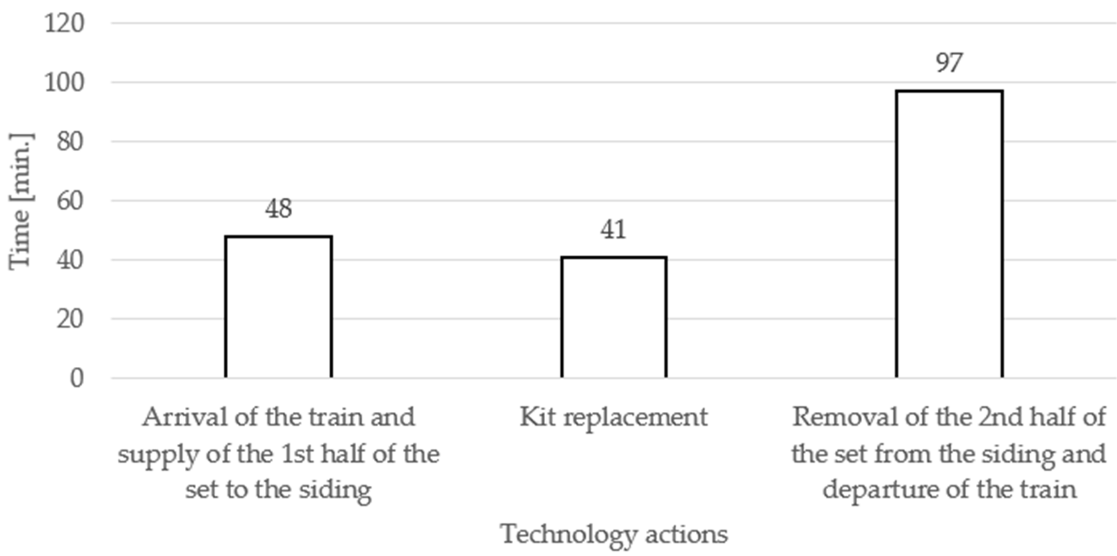

Figure 12. Comparison of procedure duration in minutes.

The longest duration is the operation connected to the train departure. This process consists of technical revision and this action must be done correctly and properly. It is a precondition for safe and fluent transportation from Trnava (Slovakia) to Tychy (Poland).

In case of the parking of wagons in the Trnava freight station, the railway infrastructure fee consists of part U_{SZ4}, according to the modified Equation (1) for this action.

$$U_{SZ4} = (24\ hours\ rate * 9\ wagons) + (24\ hours\ rate * 9\ wagons) \quad (2)$$

when the values are added to formula 1, the result is 3.51 €. Siding fees are paid to the transport company PKPCI because this railway transport company operates on this siding.

In case there are not any free tracks for the parking of wagons in the Trnava freight station, there are other costs that occur, and the transport company must pay them. These costs are mostly aimed at the use of the railway infrastructure.

There are two basic solutions:

- A train route from Tychy (Poland) to Sereď (Slovakia) by using the regular route of the train number 55306 in the section Čadca–Sereď. Later, half of the train will go from Sereď to Trnava to the Lycos siding for the loading
- A train route from Tychy (Poland) to Trnava freight station (Slovakia) by using the regular route of the train number 55306 in the section Čadca–Leopoldov and the train route number 58860 in the section Leopoldov–Trnava freight station. Later, half of the train will go from Trnava to Sereď for parking.

In real operation, the most common way is the second option. It also depends on the other circulations of locomotives. The first option is more economical due to a smaller number of used train routes, which directly saves costs for the transport company. This is the reason why the proposal consists of those procedures and the cost calculations for the usage of the railway infrastructure. Figure 13 shows the procedure of loading first half of the wagons that are going to the Lycos siding from the Sereď railway station.

No.	Action	Who	Duration
1.	Train route preparation and train arrival to Sereď	dispatcher + driver PSŽ	5 min.
2.	Unyoking the first half of the wagons	driver PSŽ	5 min.
3.	Assurement of the second half of wagons against the movement	driver PSŽ	7 min.
4.	Train route preparation and departure of the first half to Trnava	dispatcher + driver PSŽ	3 min.
5.	Train ride from Sereď to Trnava	driver PSŽ	21 min.
6.	Train route preparation and train arrival	dispatcher + driver PSŽ	5 min.
7.	Locomotive unyoking	driver PSŽ	2 min.
8.	Assurement of wagons against the movement	driver PSŽ	7 min.
9.	Locomotive route preparation and locomotive departure	dispatcher + driver PSŽ	1 min.
10.	Yoking of the first half of wagons	driver PKPCI	2 min.
11.	Entire breaking test	driver PKPCI	5 min.
12.	Train route preparation from station to siding	dispatcher	0.5 min.
13.	Shunting from station to siding	driver PKPCI	4 min.
14.	Locomotive unyoking	driver PKPCI	2 min.
15.	Train route preparation from siding to station	dispatcher	0.5 min.
16.	Locomotive shunting from siding to station	driver PKPCI	4 min.
Overall: 74 min.			

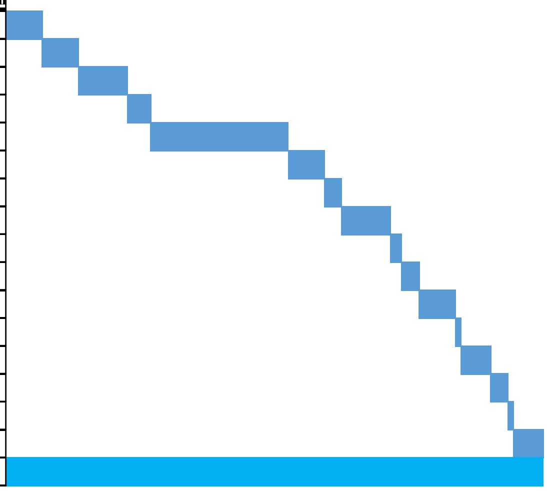

Figure 13. Procedure of providing the first half of the wagons from the Sereď station to the Lycos siding.

The duration of this operation is longer than the previous one. It is caused by the train ride from Sereď to Trnava freight station. The transport company dispatcher's actions are the same as the previous. Figure 14 shows the procedure of changing the halves of the train when one of the halves is parked at the Sereď railway station.

No.	Action	Who	Duration
1.	Locomotive route preparation and locomotive arrival to station Sered'	dispatcher Sered' + driver PSŽ	5 min.
	Train route preparation from siding to station	dispatcher Trnava + driver PKPCI	
2.	Parked wagons yoking	driver PSŽ	4 min.
	Shunting from station to siding	driver PKPCI	
3.	Train route preparation and departure from Sered' to Trnava	dispatcher Sered' + driver PSŽ	3 min.
	Loaded wagons yoking	driver PKPCI	
4.	Entire breaking test	driver PSŽ	5 min.
	Entire breaking test	driver pkpci	
5.	Train route preparation and departure of the train	dispatcher Trnava + driver PSŽ	3 min.
	Train route preparation from siding to station	dispatcher Trnava	
6.	Train ride from Sered' to Trnava	driver PSŽ	21 min.
	Shunting from siding to station	driver PKPCI	
7.	Train route preparation and train arrival to Trnava	dispatcher Trnava + driver PSŽ	5 min.
	Locomotive unyoking from loaded wagons	driver PKPCI	
8.	Locomotive unyoking from empty wagons	driver PSŽ	5 min.
	Shunting to loaded wagons	driver PKPCI	
9.	Shunting to empty wagons	driver PSŽ	5 min.
	Locomotive yoking to empty wagons	driver PKPCI	
10.	Locomotive yoking to loaded wagons	driver PSŽ	5 min.
	Entire breaking test	driver PKPCI	
11.	Entire breaking test	driver PSŽ	5 min.
	Train route preparation from station to siding	dispatcher Trnava	
12.	Train route preparation and departure to Sered'	dispatcher Trnava	4 min.
	Shunting from station to siding	driver PKPCI	
13.	Train ride from Trnava to Sered'	driver PSŽ	21 min.
	Locomotive unyoking in the siding	driver PKPCI	
14.	Train route preparation and train arrival to Sered'	dispatcher Sered' + driver PSŽ	5 min.
	Train route preparation from siding to station	dispatcher Trnava	
15.	Locomotive unyoking in Sered'	driver PSŽ	4 min.
	Shunting from siding to station	driver PKPCI	
16.	Assesment against the movement	driver PSŽ	7 min.
17.	Locomotive route preparation and departure from Sered'	dispatcher Sered' + driver PSŽ	2 min.
	Overall: 109 min.		

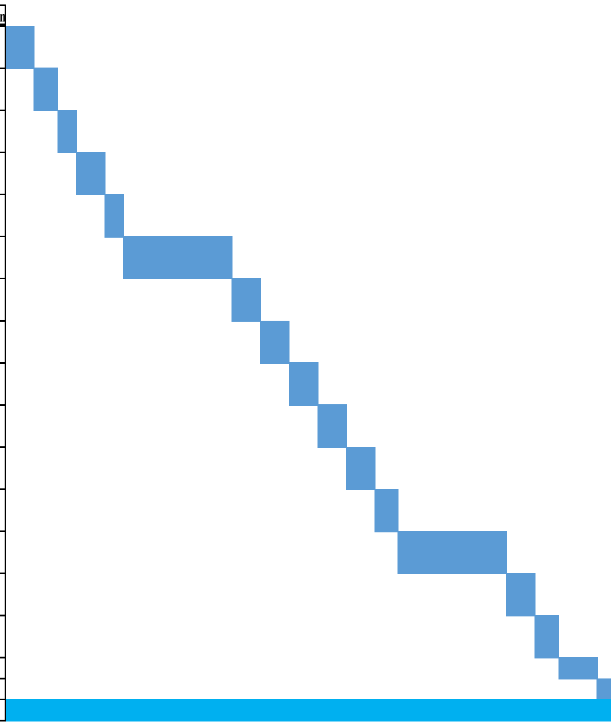

Figure 14. Technology of changing of wagons.

The changing of the wagons lasts almost 2 h. Most of the actions are done simultaneously because they are independent. Figure 15 shows the procedure of the train departure from the Sered' railway station and the connection of the second half at the Trnava railway station.

No.	Action	Who	Duration
1.	Locomotive route preparation and locomotive arrival to Sered'	dispatcher Sered' + driver PSŽ	5 min.
	Train route preparation from station to siding	dispatcher Trnava + driver PKPCI	
2.	Loaded wagons yoking in Sered'	driver PSŽ	4 min.
	Shunting from station to siding	driver PKPCI	
3.	Train route preparation and train departure to Trnava	dispatcher Sered' + driver PSŽ	3 min.
	Wagons yoking in the siding	driver PKPCI	
4.	Entire breaking test	driver PSŽ	5 min.
	Entire breaking test	driver PKPCI	
5.	Train route preparation and train departure to Trnava	dispatcher Trnava + driver PSŽ	3 min.
	Train route preparation from siding to station	dispatcher Trnava	
6.	Train ride from Sered' to Trnava	driver PSŽ	21 min.
	Shunting from siding to station	driver PKPCI	
7.	Train route preparation and train arrival to Trnava	dispatcher Trnava + driver PSŽ	5 min.
	Locomotive unyoking from the second half of the wagons	driver PKPCI	
8.	Locomotive unyoking from the first half of the wagons	driver PSŽ	3 min.
9.	Shunting	dispatcher Trnava + driver PSŽ	5 min.
10.	Locomotive yoking to the second half of the wagons	driver PSŽ + technician PSŽ	3 min.
11.	Shunting	dispatcher Trnava + driver PSŽ	5 min.
12.	Connecting wagons	technician PSŽ	5 min.
13.	Technical revision	technician PSŽ	60 min.
14.	Locomotive yoking	technician PSŽ	2 min.
15.	Entire breaking test	technician PSŽ + driver PSŽ	5 min.
16.	Train route preparation and train departure	dispatcher + driver PSŽ	2 min.
	Overall: 136 min.		

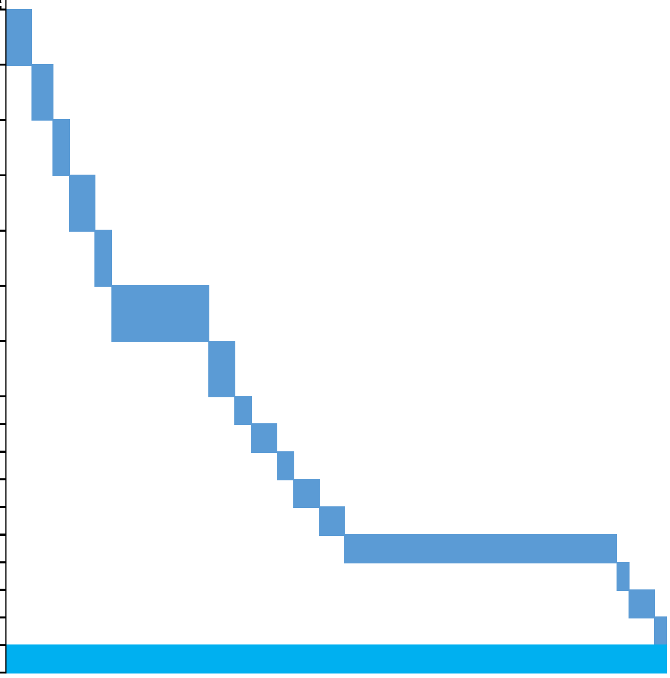

Figure 15. Procedure of the train departure.

In this procedure, there are many actions that are done simultaneously. From a time point of view, this process is the longest. Figure 16 shows the comparison of every procedure in the case of wagons being parked at the Sered' railway station.

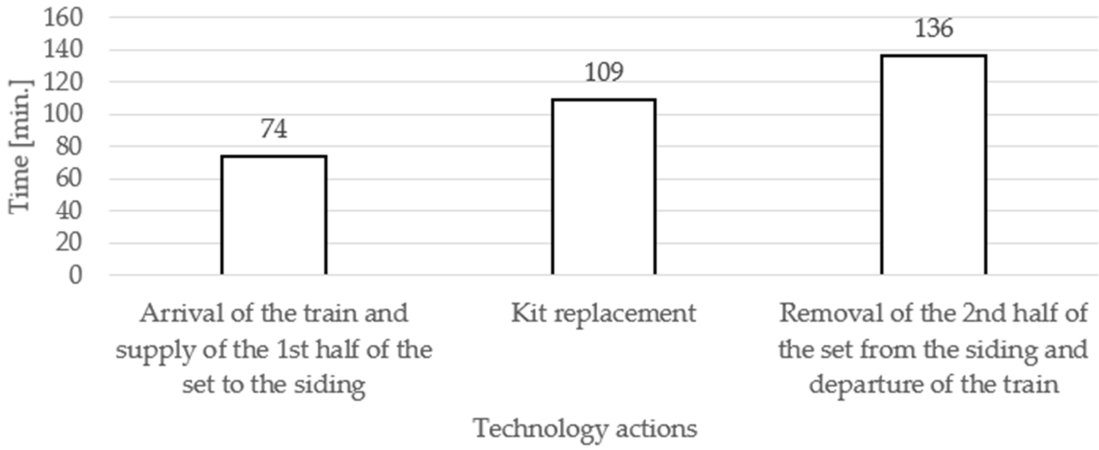

Figure 16. Duration of each procedure in minutes.

The longest procedure is the last, where the two halves of the wagons connect at the Trnava freight station and the train departs. It is the same case as was shown in the cases of parking the wagons directly at the Trnava railway station. The duration is longer due to the train ride from the Sereď railway station to the Trnava freight station and vice versa.

The last part of the research was the cost calculation. The railway infrastructure fee was calculated. Procedures where wagons are parked at the Trnava freight station were compared with the procedures where wagons are parked at the Sereď railway station. Table 5 shows the inputs for this calculation.

Table 5. Inputs for railway infrastructure fee calculation [12].

Railway Line Category	Type and Weight of the Locomotive	Railway Station Category
I. Trnava–Trnava freight station (0.6 km) II. Sereď–Trnava (14.2 km)	193.820—87 t	Trnava freight station – B_{ND} Sereď-C_{ND}

Besides these data it is necessary to know the weight of empty wagons and the weight of the load. These data are shown in Table 6.

Table 6. Weight of empty wagons and load [23].

No.	Empty Wagon Weight (t)	Load Weight (t)
1	22.5	44
2	23.1	44.2
3	22.9	44
4	22.9	43.8
5	22.8	43.8
6	23	44
7	22.8	44.5
8	22.6	45
9	22.7	44.4
10	22.8	44.4
11	22.9	44.4
12	22.7	44.1
13	22.7	44.3
14	22.7	44
15	23	43.5

16	22.8	44.1
17	22.9	44.1
18	22.6	44.5

Gross ton-kilometers are necessary to calculate the part U_3 and they were calculated separately for the loaded and empty half of wagons according Equation (3).

$$\Sigma gtkm = (wagon\ weight + full\ load\ weight + locomotive\ weight) * route\ lenght \tag{3}$$

The use of the railway infrastructure fee must be calculated partially according to the steps that are shown in the procedures. It is described in Table 7.

Table 7. The use of the railway infrastructure fee in the case of wagons being parked at Sereď.

First Half of Empty Wagons—Ride from Sereď to Trnava	Second Half of Empty Wagons—Ride from Sereď to Trnava	First Half of Loaded Wagons—Ride from Trnava to Sereď	First Half of Loaded Wagons—Ride from Sereď to Trnava
U_1: 0.11 + 2.24 = 2.35€	U_1: 0.11 + 2.24 = 2.35€	U_1: 0.11 + 2.24 = 2.35€	U_1: 0.11 + 2.24 = 2.35€
U_2 = 0.6 + 13.16 = 13.76€	U_2 = 0.6 + 13.16 = 13.76€	U_2 = 0.6 + 13.16 = 13.76€	U_2 = 0.6 + 13.16 = 13.76€
U_3 = 0.19 + 4.36 = 4.55€	U_3 = 0.19 + 4.36 = 4.55€	U_3 = 0.46€ + 10.28 = 10.74€	U_3 = 0.46€ + 10.28 = 10.74€
U_{SZ3} = 20.99€	U_{SZ3} = 20.99€	U_{SZ3} = 13.42€	U_{SZ3} = 20.99€
U_{SZ4} = 3.51€			
Σ: 46.16€	Σ: 46.16€	Σ: 46.13€	Σ: 53.70€

Using the railway infrastructure in the case of wagons parking at Sereď the railway station costs 192.15 €. These costs must be paid to the railway transport company. Advantages of this solution are the improvement of the conditions of infrastructure management and the improvement of process efficiency for the transport company.

Table 8 shows quality criteria and their values. The highest importance rate was based on a long-term survey and advice from transport experts.

Table 8. Results of the quality evaluation.

Quality Criterion	Importance Rate	Level of Perceived Quality	Ideal Ratio of Satisfaction	Real Ratio of Satisfaction
Transport price	5	2.5	25	12.5
Transport time	4.5	2.25	22.5	10.1
Communication between customer and transport company	3	1.5	15	4.5
Reliability	4	2	20	8
Σ	-	-	**82.5**	**35.1**

According Equation (1), the resulting value of the entire transport quality is shown as a percentage. This number shows how much the real perceived quality of transport meets the expected quality of transport.

$$Resulting\ quality\ ratio = \frac{35.1}{82.5} \tag{4}$$

Customers were satisfied with this transport at the level of 42.5%, which can be increased by changes in the procedures that are described above.

5. Discussion

In the conditions of the liberalized railway transport market, it is necessary to sustain and improve the efficiency of every process that is connected to transport. Competitiveness of railway transport could be higher to other transport modes. Currently, only 10–30% of transport is done by freight trains in EU countries. This value should be increased to 50–70% due to ecological and economical aspects connected to infrastructure and impacts on the environment. This goal can be done only step by step.

In the case study, one of the regular freight transports of the transport company PSŽ was analyzed. Trnava malt factory was one of the satisfied customers of this transport company. However, there were not only positive experiences with this transport. There were some cases when no free tracks were at the Trnava railway station, and therefore alternative solutions were found. These alternatives should be good from a quantitative as well as a qualitative point of view. The best solution was to park the wagons at the Sereď railway station, which was analyzed in the research. Advantages of this research are:

- Theoretical—deep analysis of the current conditions based on other similar research
- Practical—proposals could be used by every transport company that have similar problems. The solution is determined to be pseudo-optimal, because many inputs can influence it and in other railway stations, there may be also no free tracks.
- Scientific— the application of technology and the transport quality evaluation from a customer satisfaction point of view. The liberalized transport market offers a big choice of transport companies for customers that leads to competitiveness. Transport companies must make their offer as wide as possible. The calculation of fees for using the railway infrastructure shows the impacts of technological changes to the costs of the transport company.

The most important output of this research is the improvement of the transport process that is focused on last mile-specific issues. These issues directly influence the operational fluency in railway stations. It is proven that there are railway stations that have problems with the capacity of free tracks. The worst situation is at border stations. Further research should be aimed at issues connected to them [31,32].

Border stations have specific status in the Slovakia railway infrastructure. There are not free tracks very often and the closest stations have similar problems. In many cases, it is caused by locomotive drivers who do not have permission to travel in another country; therefore they must park the train at the border station and wait for the locomotive driver from the other country [33].

A possible solution is also the complex reconstruction of selected railway stations, but there would be a necessary huge number of investments. Due to this reason, it is necessary to combine scientific research with practical experiences, as was the subject of this research. It is the best way to find the solution for these problems [34].

6. Conclusions

The capacity of railway stations and sidings are closely related to a logistic process called the last mile. The main goal is to satisfy the customer. In specific conditions of railway transport, the infrastructure manager can also be satisfied because the capacity of the tracks could be used optimally.

In the research, there are two technologies of trains that go to the Lycos siding in Trnava. This problem was analyzed from a railway tracks capacity point of view. The number of free tracks at the Trnava railway station is limited and length of siding tracks are not enough for the whole train. Procedures were compared according to the quantitative determinant— the railway infrastructure fee. Figure 17 shows the comparison of these procedures according to infrastructure costs.

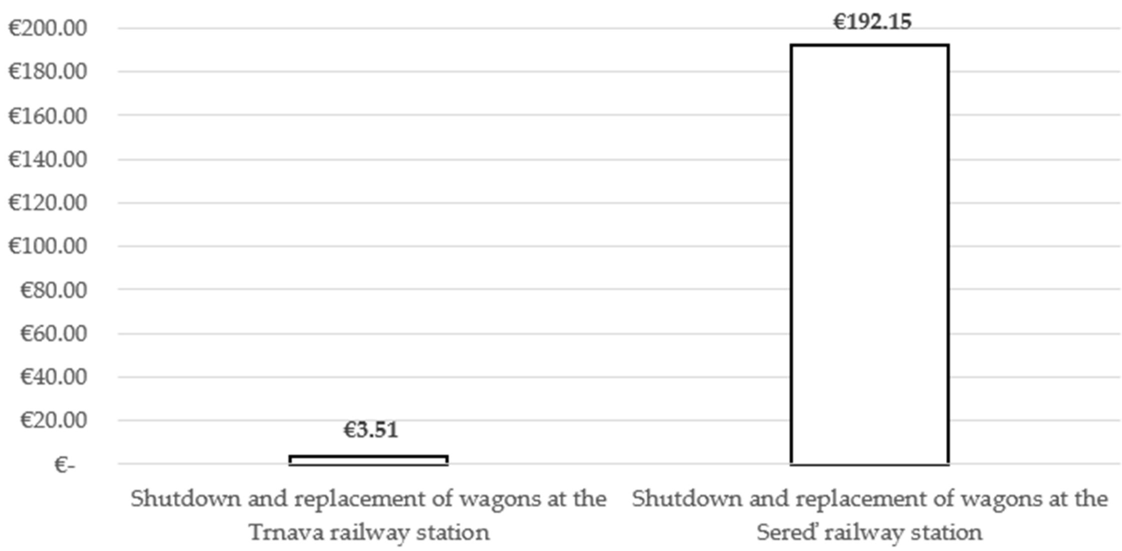

Figure 17. Comparison of costs for the usage of the railway infrastructure.

The cost difference between these procedures is 188.46 €. From the transport company point of view, it is cheaper to park wagons at the Trnava freight station, but there is a problem with the capacity of free tracks. Correct functionality of the entire process is dependent on concordance of these two procedures. In some cases, the parking of wagons at the Sereď railway station could be more efficient. It is necessary to think about possibilities to extend the length of tracks directly in the Lycos siding. This possibility is more expensive because there must be investments to the railway infrastructure.

Figure 18 shows the final evaluation of the entire transport quality. The combined method with the selected models of Liljander and Strandvik, as well as the multicriteria evaluation and model of Lynn Schostack are accompanied here.

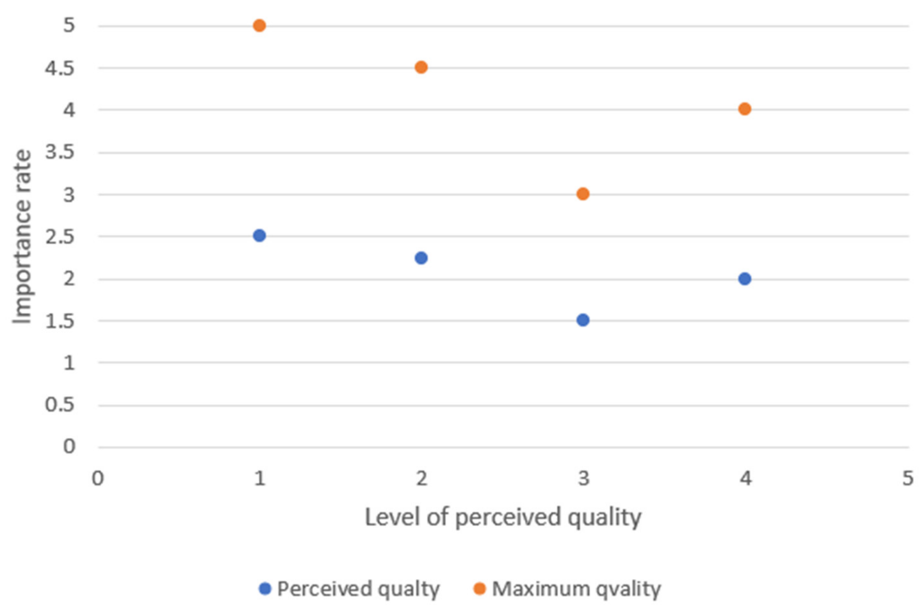

Figure 18. Results of quality evaluation.

The results of quality evaluation show the expected output—transport price is the most important criterion for the customer. After the transport price, there is the delivery time. It is necessary to improve the entire quality of transport by decreasing the transport time and other possibilities that were described above.

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