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Evaluation Methodology of the Railway Stations Using the AHP Method in the Transport Hubs from the Freight Transport Point of View

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Abstract: Currently, it is necessary to support not only public passenger transport at the expense of individual car transport but also to ensure the modal split of goods from road transport to railway transport. Moreover, it is important to modernize the railway infrastructure, especially hubs and other important railway stations in important settlements and big cities. Therefore, it is necessary to constantly invest in railway lines as well as railway stations. The contribution deals with the determination of the methodology for the evaluation of railway stations in freight transport based on current scientific publications and the AHP method. Its main goal is to determine the size of the peak on the network-railway station on the infrastructure manager's railway network. One of the benefits is the subsequent determination of the next procedure from the given peak in terms of operation, considering the economic complexity of the entire procedure. The methodology is preceded by an extensive analysis of input data in Slovakia and abroad. This methodology defines the parameters or factors that influence decisions for a particular railway freight station. Subsequently, based on the proposed methodology, a practical application is also developed, within which four railway stations on the ŽSR network are evaluated. In a broader sense, the contribution also points to improving the quality of railway infrastructure in cities.

Keywords: railway stations; freight transport; significant cities; evaluation; AHP method; transport hubs

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1. Introduction

Transport is an essential sector of the national economy, the actual product of which is the transport of people, animals, and goods. In recent years, railway systems have played a significant role in transportation systems due to the increase in demand for conveying both cargo and passengers [1]. The transport system can be seen as a complex process involving transport services, which can be divided into passenger and freight transport systems [2]. Consequently, it is necessary to distinguish between road, rail, water, air, and other specific transport systems [3]. The rail transport system should be an important transport system that, based on its advantages (high transport capacity, safety, and environmental friendliness), should be the backbone transport system not only for passenger transport but also for freight transport, particularly over medium and long distances, to be able to provide an adequate level of service over time [4–6].

A specific case is rail transport in the city. A significant city is a parameter or factor in this case, but on the other side, we have many insignificant or small cities where rail freight transport is the role of larger cities. In the case of our research, the term significant city refers to a city with great transport and operational importance, especially from the point of view of rail freight transport. Each city considered (Spišská Nová Ves, Strekov, Horné Sŕnie, and Záhorská Ves) has the character of either a large, medium, or small city in Slovakia. Although the assessed railway freight stations in these cities are not part of the central railway station, they have their importance on the railway network. They are railway freight stations, which by their nature belong to train-forming stations. It is thus a mix of railway stations in large, medium, and small cities, which by their nature belong to the important ones. Therefore, it is necessary to adapt the railway infrastructure in the city according to the transport needs of its inhabitants, with an emphasis on building railway stations and stops in the most suitable places. From the point of view of freight transport, it is necessary to assess whether it is a train-forming station or only an intermediate station [7,8].

From the point of view of marketing, transport is considered a service. A service is defined as any activity or benefit that one party can offer to another that is non-material in nature and does not result in the acquisition of ownership. On the rail transport market, the supply side is a railway company (carrier) offering transport services for the transport of goods (as well as people) in space and time. On the demand side is the customer, who is a natural or legal person requesting the relocation of the goods to their destination. The customer can also be the carrier itself, for whose needs the service is provided, or an intermediary, for example, a forwarder. So, the criteria for starting freight transport planning in any city, be it large, medium, or small, is primarily the demand and supply of freight carrier services and the available technical–technological base of the railway station in that city [9]. The interest of the carrier is to maintain and expand the market for its products/services and to maximize the economic return (profit). The allocation of railway infrastructure capacity is also an important criterion.

The rail freight system is a transport system whose primary objective is to meet the transport requirements of customers. The transport requirements are the movement of consignments, which are the transport elements [10]. Depending on the field of the rail transport system under consideration, a consignment may be a lump consignment, a container, or a loaded railway wagon [11]. Each transport element is part of one of the following processes:

1. Entry from the surroundings.
2. Gathering into batches or kits.
3. Forming a set—in our case, a train.
4. Movement of the assembly along sections of the transport network.
5. Sorting the set at a node with subsequent assembly into the next set.
6. Exiting an element from the network.

Entry or exit to surroundings may also be a transition to a hierarchically higher or lower transport subsystem [12]. An important element of the railway transport system is the railway station. It is a transport station with track branching allowing crossing and overtaking of passenger and freight trains, or special purpose trains. From the perspective of graph theory, the railway station is considered a vertex on the network [13]. Each vertex is generally represented by its size and facilities. As a rule, a railway station not only provides the passenger handling process (purchase of travel documents, luggage storage, catering services), but from the point of view of the rail freight transport system, it is also about the performance of freight wagon handling—loading and unloading of freight wagons, their transport equipment, and, for a larger number of tracks, also the marshalling of vehicles (marshalling yards) [14].

At present (2023), there are a total of 316 transport points, i.e., railway stations and border crossing stations, on the network of Slovak railways, whose infrastructure manager is the company Železnice Slovenskej republiky (Slovak Railways—hereinafter ŽSR) [15]. These transport points have different types of dispatch authorizations. Approximately 97% of them have dispatch authorizations for the transport of wagon consignments [16]. In addition, railway stations have various technical equipment that facilitates the handling of wagon consignments. Due to the liberalization process and the increasing interest of carriers in using rail freight services, the performance of rail freight transport has gradually started to increase [17,18]. For example, between 2015 and 2016, the transport of goods increased by 10,141 million tonnes [19,20]. However, not all railway stations on the ŽSR network were properly equipped for the increase in transport. New carriers have different requirements for the infrastructure manager, and due to the obsolete equipment of some railway stations and inappropriate working technology, these requirements of carriers and freight forwarders are often not feasible.

There is no methodology for the assessment of railway stations from the freight transport point of view on the ŽSR network. The significance of this deficiency lies in the failure to determine the importance of individual transport points, which translates, for example, into the investments made by the infrastructure manager. The methodology we have developed will be of particular benefit to the infrastructure manager, as it will enable him to decide how to proceed with a particular station on the network. At the same time, when relocating rolling stock, this methodology can also be a tool for carriers.

The main objective of the paper is to propose a methodology for a comprehensive assessment of railway stations from a freight transport perspective. Even though the evaluation of railway stations is carried out based on several sub-criteria, a comprehensive methodology for the evaluation of railway stations has not been developed. The tool to achieve the objective is the transformation and synthesis of these evaluation criteria into a single aggregated indicator of railway stations, comprehensively expressing their importance from the network analysis point of view. The transformation and synthesis are carried out through Saaty's method, a tool of multicriteria analysis. The practical benefit of the proposal of such a methodology will be the expression of the importance of each railway station under study and may have a decisive influence in the decision-making process on the allocation of centers on the network and the creation of their respective attraction districts.

2. Literature Review

Railway station evaluation can be carried out from different perspectives and levels, which will be reflected in a literature review that broadly captures different evaluation perspectives.

In the paper [21], the authors make an identical attempt to evaluate the railway stations in India from the perspective of passenger transport. Since the Indian National Railways has 68,000 kilometers (km) of track length, manages a total of 7318 railway stations, and carries an average of 2,300,000 passengers annually, this methodology is more than necessary. Its scientific basis is formed by the Saaty method, which determines the importance and weight of each railway station. As a result, railway stations are ranked according to their importance, and measures can be implemented to increase the attractiveness of a railway station to passengers.

Our proposed methodology may result in the need for a new freight-oriented station. In such a case, the article [22] is useful, which discusses the construction of new railway stations from the perspective of the urban planning of a given city. The aim is that the new station should form a compact whole with the city and not undermine its integrity.

Although our proposed methodology does not directly address the capacity of railway stations and lines, as it is, for example, in the research [23,24], this is one of the reasons why we are proposing the methodology. There is a capacity problem at large train and yard stations on the railway network, particularly when shutting down sets of empty or loaded wagons [25]. At the same time, there is a problem with the capacity of the adjacent track sections to individual railway stations in terms of competitiveness with road freight transport, as it is in the research [26,27]. This results in a preference for road freight transport, which is more flexible and better able to meet customer requirements. In this respect, the paper [28], which deals with the capacity of single-track lines in the context of the completion of switches at railway stations, can help and extend our research. The authors' research includes three levels: using an analytical method, a custom simulation model, and then the Open Track program.

The urgency of the railway line capacity problem and the associated capacity problem of railway stations is also addressed in [29], which solves this problem using a metric-based approach. Linking our research and the solution to this problem would be particularly helpful in planning the most capacity-intensive elements, such as different types of tracks. The attractiveness model of railway stations is also addressed in the environment of increasingly popular high-speed railways. Using a coworking background in a selected railway station, the authors of the paper [30] try to create a model in a Geographic Information System (GIS) that can assess the attractiveness of individual railway stations based on this system. Whether a train stops at a given station or not will be reflected in the railway infrastructure charge in addition to passenger preferences. It can therefore be stated that their contribution, as well as our own, lies in the operational and economic solution to this issue in the railway sector.

The capacity problem, especially at marshalling and train-forming stations, is created by the occupation of the tracks by wagons. The paper [31] solves this problem in terms of the traffic role in the framework of operational analysis. The model was created based on the selected 36 stations on the China Railway network. The results demonstrate the success of the model in terms of reducing the utilization of each railway station. The utilization of railway stations has a direct impact on the quality of service. The quality of service subsequently influences the usability of freight or passenger rail transport. In [32], the authors try to find out the preferences of passengers based on factor analysis and confirmatory factor analysis. Using a sample of 370 passengers and 18 trains, it is shown that factors such as station service, safety, and information are prioritized by passengers.

A very important aspect of railway transport is its favorable carbon footprint, which is zero at the place of transport, especially with electrified railways. It can mean the carbon footprint, which is the total amount of greenhouse gases (including carbon dioxide and methane) that are generated by our actions. For example, the average carbon footprint of a person in the United States is 16 tons, one of the highest rates in the world. Globally, the average carbon footprint is closer to 4 tons. In the article [33], the authors deal with the problem of interchanges and connections in railway stations between long-distance and regional transport based on a connecting Europe facility (CEF) project from the European Union. This pushes for the use of rail as a supporting mode of transport. In freight transport, the results of the authors' research could be translated into the technology of the work in switching carriages between long-distance freight trains and local freight trains. As a result, this technology would be assumed to shorten the occupation of transporting and handling railway tracks.

The accessibility of railway stations increases their attractiveness for both passenger and freight transport. In passenger transport, a methodology for assessing the attractiveness and accessibility of railway stations was developed based on the paper [34]. Stations in the Metropolitan Association of Upper Silesia and Dąbrowa Basin (Metropolis GZM) were evaluated. In freight transport, the accessibility of railway stations could be added to our proposed methodology based on the elements leading to them, such as roads, loading ramps, or warehouses for short- or long-term storage of goods. Another issue is the duration of loading/unloading at railway stations, especially when general loading and unloading tracks are occupied if there are a limited number of them in the station. The paper [35] addresses the problem of loading/unloading time and related operations in the context of a simulated annealing algorithm. It is a generally applicable model (algorithm), but it does not consider specific examples from individual countries. This algorithm is shown to be one of the most accurate, resulting in favorable time implications for the loading/unloading technology and the associated shift at the selected experimental station. The issue of financing rail transport, whether passenger or freight, is constantly coming to the fore. The paper [36] deals with the issue of financing the construction or redevelopment of railway stations in India through public-private partnership (PPP) projects. At the same time, a factor analysis has been carried out on a sample of 250 respondents, which includes the transformation experience of Indian Railways.

All parts of the railway infrastructure are complex and demanding to maintain and keep in working order. It brings to the fore the question of what to do with railway infrastructure that is not being used. Article [37] analyzes the state of an unused station building in Mozambique, which is listed as a heritage site of the country. It also proposes solutions of a static-economic nature to preserve this building. There are also many disused railway lines in Slovakia, which are not expected to be used even after the implementation of our evaluation methodology. An extension of our research is also offered in the field of railway infrastructure conservation. A comprehensive solution would help reduce the cost for the infrastructure manager to maintain such infrastructure.

The study [38] analyzed the regional differentiation in railway development in Serbia with causal interference. The research has been conducted based on secondary data collected from multiple sources, and the existing synthetic indicator was applied to classify eight states based on their railway infrastructural status. An alternative synthetic indicator approach has been proposed and found to be more efficient than the existing synthetic indicator. The causality of such unequal development has been analyzed through a correlation test by defining the composite infrastructure index. The analysis revealed that railway infrastructure significantly influences Serbia's economic and social development. The service area of railway infrastructure indicates the potential zone for future growth.

A special group of railway stations are private sidings for various enterprises in different industries. Article [39] discusses the possibility of collecting fees from carriers/customers to operate an intermodal terminal in South Korea. The financial issue of the redevelopment of railway stations in Italy is also addressed in the article [40], whose authors compare the return of the whole project through a cost-effectiveness analysis (CEA) and a cost-benefit analysis (CBA).

Risk monitoring and risk prediction are of great significance to improving the safety of urban rail operations. The article [41] proposed a risk analysis method for urban rail operation accidents that takes risk factors, risk points, and risk events as nodes to form a network and combines the interaction between risk points to evaluate the safety of the whole system. Based on the analysis of the existing urban rail transit infrastructure and operating environment, the authors put forward the risk factors and risk points that may cause risk events and combine the mechanical connection, electrical connection, and signal connection among risk points to deeply explore the interaction between risks so as to find the key risk points that cause accidents and evaluate the safety of the whole system. The results show that the proposed risk analysis method can provide effective theoretical support for risk monitoring.

It is clear from the literature review that the research conducted by us is unparalleled in scientific circles. There are many related industries evaluating railway stations, especially passenger transport, based on different criteria. We see that these criteria are also applicable to freight transport, but they do not provide a coherent methodology. Before the proposal part, it is still necessary to mention that the current system of railway freight transport in EU conditions is not efficient and sustainable, as several problems arise with monitoring and tracking of rail freight transport. Determining the demand and supply forecast is also currently not effective. Also, there are currently no specific publications or documents that describe the issue of generating freight traffic, as well as the planning and layout of railway stations on the railway network. It is a generally applicable model (algorithm), but it does not consider specific examples from individual countries. Currently, in Slovakia, the process is carried out through the internal materials of freight carriers and the infrastructure manager. Also, for these reasons, it is necessary to propose a specific and unique methodology for the evaluation of railway stations, which will also help us to solve these raised problems and questions within the framework of further research on the mentioned issue.

3. Materials and Methods

As a first step, it was necessary to choose a mathematical and statistical method for determining the importance of each railway station. The choice fell on multicriteria analysis methods. It is these methods that underpin the comprehensive draft methodology described below. The choice of a particular one depended on a comparison of their advantages and disadvantages, as shown in Table 1.

Table 1. Advantages and disadvantages of selected methods of multicriteria analysis [42].

Methods	Advantages	Disadvantages
decision matrix (DMM)	relatively low time requirement simplicity of procedure	high degree of subjectivity subjective determination of the weight of the criteria
modified decision matrix (FDMM)	relative simplicity of the procedure elimination of subjectivity in determining the weights and influence of criteria	relatively large differences in the evaluation of individual variants and criteria when determining the weight of the criterion or the evaluation of the alternative equal to 0, they have no effect on the overall evaluation
analytical multilevel method—Saaty method (AHP)	data adaptation the possibility of using software tools	higher difficulty of the procedure the need for relevant data

Table 1 shows that the analytical multilevel method (hereinafter referred to as the Saaty method or the AHP method) is the most suitable because this method is the most accurate and exact. It shows the ratio of its advantages and disadvantages when using other methods. An important part of Saaty's method is the AHP method, which was created in the late 1960s and early 1970s, and its author is the American professor Thomas L. Saaty. Saaty's analytical hierarchical process offers a methodology that allows modeling complex decision-making situations and selecting appropriate solutions. This procedure was developed to help overcome complex problems. Although it was not originally intended exclusively for collective decision making, nowadays, due to its systematicity and transparency, it is mainly used in group decision-making situations. The basic objective of the AHP method is the optimization of decision-making processes through the prioritization of variables in complex decisions in which quantitative and qualitative factors are combined. The method focuses on differentiating individual criteria according to their degree of importance. AHP compiles the order of decision items using comparison or correlation between individual pairs of items forming the decision matrix. Appropriate comparisons subsequently generate weight values [43]. The flexibility of the AHP method as a model for decision making helps to clearly establish the optimal solution among other possible solutions. This decision making can be divided into three different groups (hierarchy, priorities, and consistency). In the AHP method, when creating a structured hierarchy, the system consists of the main objective and then follows a group of criteria, which, as necessary, are broken down into further sub-criteria up to as many levels as the problem requires. The system of hierarchy creation helps, on the one hand, more clearly define all the decisive elements, but it also helps to recognize the links between them. Since the processes of creation hierarchies in the AHP method are unique to individual decision-making processes, there are no data creation procedure-specified hierarchies.

However, a major disadvantage is the considerable degree of subjectivity since the rating, or the determination of the importance weights, is determined by the rater. The method mentioned is the most suitable considering the status and parameters of the input data. It is an aggregation method used in mathematical–statistical models, where the calculation of a simple or weighted arithmetic mean and sum is used, where the input data are a set of experimental results or a set of survey results. We wanted to use known alternative solutions to solve an unknown problem. The aim of the mentioned methodology is not to present new facts but to find the new possibilities of this methodology, in our opinion. The other methods were not suitable to be used due to the insufficient relevance of the data in question. For example, to use economic analysis methods (CBA, etc.), we would need to know several important economic indicators, but this is not the subject of this research. For the needs of established and resolved research, the multiple-criteria decision-making methods are sufficient considering the stated goal and results of the paper.

A disadvantage of the AHP method is a certain degree of subjectivity. To reduce the degree of subjectivity, employees of selected railway companies were approached by means of a questionnaire survey. Interviews and consultations with railway companies took place exclusively in person, namely with significant experts dealing with this issue. Each of them was familiar with the railway station evaluation process as well as research methods. Subsequently, they expressed their agreement with the established methodical procedure. All consultations took place independently of each other. The company ZSSK CARGO a. s. took first place because it is a Slovak national freight carrier that has the highest transport performance at almost all railway stations on the Slovak railway network. The other carriers are private carriers that also operate on the territory of the Slovak Republic. The forces of action and influence are equalized on the market between individual carriers. This is also proven by the operation of carriers at railway stations. However, each carrier may request a different service from the infrastructure manager. Since there are relatively many of them, it is essential that the employees of the infrastructure manager consider the individual requirements and adapt the operation to them. The results obtained using the multi-criteria analysis method within the decision-making process should also help with the adaptation of the operation. When providing the capacity of the railway station and its equipment, the strength of the importance of the use of individual equipment for railway companies can be determined. The most important private carriers were addressed within the mentioned consultations. For better clarity, they were included in the group "other carriers". These are the following:

- LTE, s. r. o.,
- RTI, a. s.,
- PSŽ, a. s.,
- PKP Cargo International, a.s.

Individual railway stations were selected in such a way that each type of railway station was represented. Specifically, a railway station with a low range, a medium range, and a high range of transport performance, as well as the specific case of a border crossing station. A more precise selection according to specific sub-criteria is shown in Table 2.

Table 2. Rated railway stations.

Selection Criteria	Railway Station
Train formation station with a locomotive depot	Spišská Nová Ves
Intermediate railway station	Strekov
Border station	Horné Srnie
Arrival station on the sidetrack	Záhorská Ves

The names of individual selected railway stations are marked in a dark red box on the map of the Slovak railways in Figure 1.

Table 3 shows the importance of the weights in determining the criteria, which was also used as a scoring scale in the questionnaire survey.

The most important part of the proposal is a comprehensive proposal for a methodology for the assessment of railway stations from the point of view of freight transport. Figure 2 shows the process of developing the methodology.

The formulation of the research question and the corresponding hypothesis statement related to it are presented in Table 4.

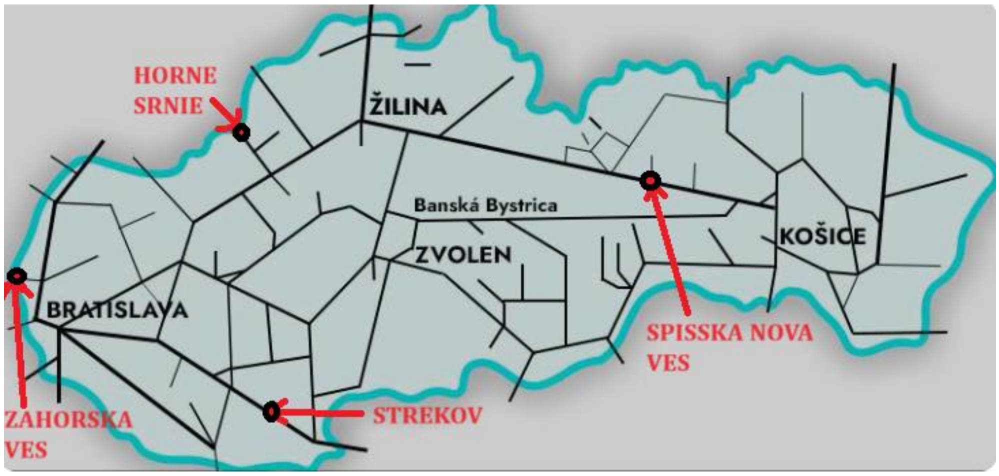

Figure 1. The selected Slovak railway stations.

Table 3. The importance of assessment in determining weights [42].

Weight	Describe
1	Elements are equally important.
2	An element in a row is slightly more significant than an element in a column.
3	An element in a row is weakly more significant than an element in a column.
4	An element in a row is generally quite more significant than an element in a column.
5	An element in a row is much more significant than an element in a column.
6	An element in a row is almost demonstratively more significant than an element in a column.
7	An element in a row is demonstratively more significant than an element in a column.
8	An element in a row is much more significant than an element in a column.
9	An element in a row is totally more significant than an element in a column.

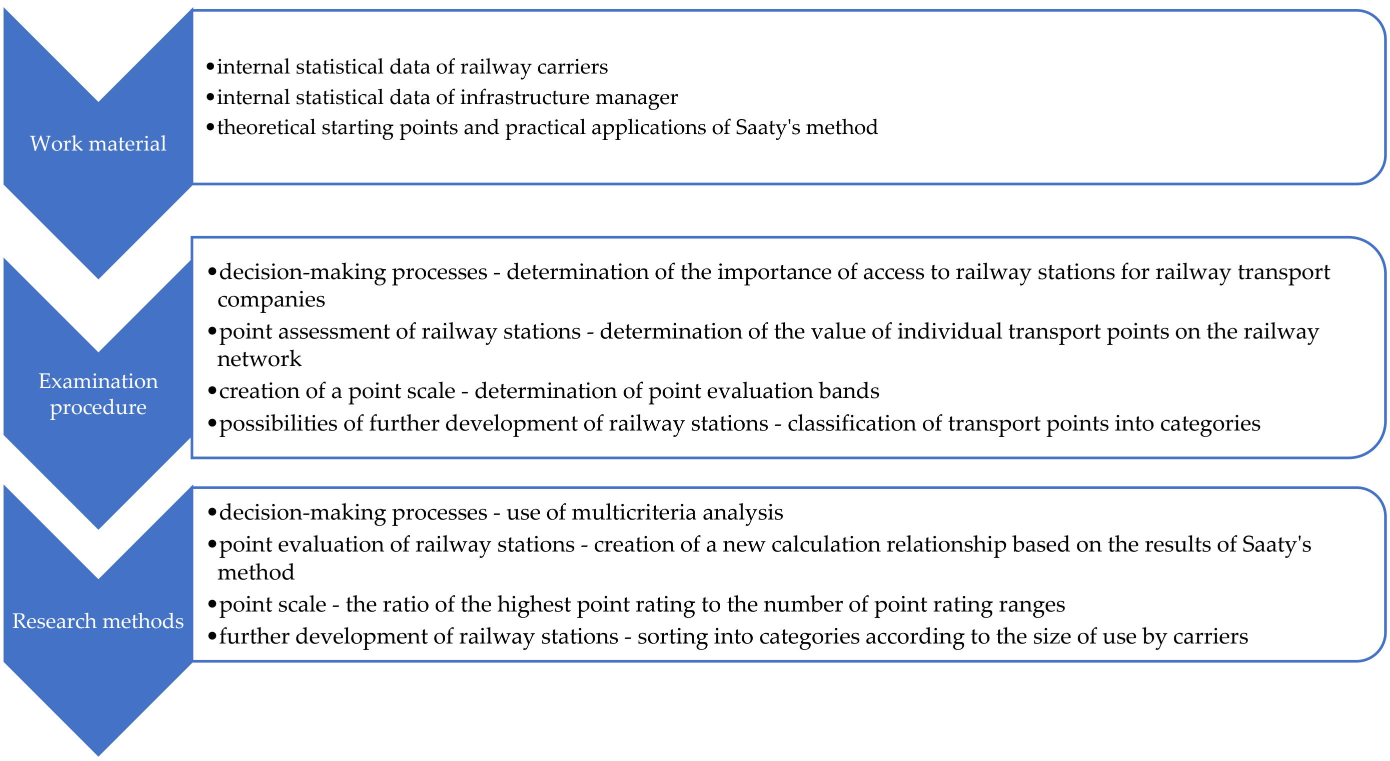

Figure 2. Process of developing the methodology.

Table 4. Formulation of research questions with establishment of hypotheses.

Research Question	Hypotheses
How will the rate of use of railway stations by railway companies be reflected?	H0: The rate of use of railway stations will be higher by carriers and lower by the infrastructure manager. H1: The rate of use of railway stations will be lower (or the same) by carriers and higher by infrastructure managers.

In the research, questions will always be answered and hypotheses will always be tested, one accepted and one rejected. In general, the stated hypothesis can be expressed through propositional logic. In this case, it is an implication. It is a logical operation that forms a compound statement from two statements using a logical conjunction that corresponds to the conjunction if-so. So, in practice, this means that if the H0 hypothesis is valid, then the H1 hypothesis will not be valid, and vice versa, if the H1 hypothesis is valid, then the H0 hypothesis will not be valid. It can be expressed as follows:

$$\text{H0} \Rightarrow \neg\,\text{H1}$$

$$\text{H1} \Rightarrow \neg\,\text{H0}$$

For the purposes of propositional logic, we can mark the rate of use of railway stations—RS, use by carriers—CA, and use by infrastructure managers—IM. We can also mark H0 acceptance as H0a and H1 acceptance as H1a. Subsequently, the acceptance of individual hypotheses can be expressed as follows:

$$\text{H0a} \Leftrightarrow \text{CA} > \text{IM}$$

$$\text{H1a} \Leftrightarrow \text{CA} \leq \text{IM}$$

3.1. Determining the Importance of Access to Railway Stations for Railway Undertakings

There are several different methods that have essentially the same objective, namely the assessment of several solution variants according to a given set of criteria and the determination of the variant order. The different methods differ in how the weight of each criterion is determined and how the degree to which each solution variant meets the chosen criteria is numerically evaluated [44]. All these methods are listed in Table 1.

Each of these methods is applicable to the railway environment. Based on the advantages and disadvantages of each method, the most accurate method is selected. Table 5 provides an overview of the system entities and decision makers under evaluation.

Table 5. Indication of the evaluated criteria and subjects.

Evaluated Criteria	Marking	Evaluated Subject	Marking
rail weights	A	ŽSR	I.
parking tracks	B	ZSSK CARGO	II.
shunting by infrastructure manager	C	Other carriers	III.
private sidings	D		
loading and unloading	E		
border crossing stations	F		
locomotive depots	G		
technical equipment	H		
transport service lockout	I		

These criteria represent services at railway freight stations. Because of better clarity and an efficient way of inserting them into the formula, they are marked with the letters A–I. All data used are obtained from the internal materials of the carrier ZSSK CARGO from 2019, as it is the last year so far from which relevant data are available that has not been distorted by the COVID-19 pandemic or the war in Ukraine. Evaluated subject ŽSR is the

Slovak infrastructure manager, ZSSK CARGO is the state railway freight carrier, and other carriers are all the carriers that provide their services on the ŽSR network, and they have a valid license to operate rail freight transport. We have grouped them into one group (other carriers) because they have low transport performance on the ŽSR network and most of their performances are directed abroad. Therefore, it is not relevant for us to evaluate each of them separately.

The carrier ZSSK CARGO is a state carrier and one of the largest railway freight carriers in Slovakia. In 2022, they transported 28,851 thousand tons of goods. The transport performance reached a value of 5861 mil. net tonne kilometers and an average transport distance of 203.2 kilometers. In the year-on-year comparison, we recorded a decrease of 2534 thousand tons, and by 490 mil. kilometers, the average transport distance increased by 0.8 kilometers. The performance of ZSSK CARGO in 2022 was significantly influenced by the economic development in the Slovak Republic and neighboring countries because of the military conflict in Ukraine. In 2022, they began to implement a significant new transportation of oil products from the Slovak Republic to Ukraine in the volume of 107 thousand tons [45].

A brief description and explanation of individual criteria are as follows:

- The use of rail weights (A) is represented by the number of wagons weighed in 2019. It does not consider the type of rail weight installed in the railway station or the number of wagon axles.
- The use of parking tracks (B) is represented by the number of wagons laid up for more than 24 h in 2019, as there is a specific charge. No account is taken of whether the wagons are loaded or empty.
- The use of shunting by infrastructure manager (C) is represented using the number of 2019 wagons that the infrastructure manager has shunted at the request of the carrier at the station.
- Private siding utilization (D) is represented by the number of 2019 wagons that have been moved to the private siding. The calculation also considers the wagons that are deposited on it.
- The loading and unloading (E) of wagons is represented by the number of wagons from 2019 that are loaded or unloaded in national transport. This indicator also includes the use of technical equipment, in particular ramps, which cannot be quantified per number of wagons. In practice, this means that if goods have been loaded onto wagons using a ramp or other equipment, their use is represented as the number of wagons loaded or unloaded.
- Import and export (F) of wagons is an indicator of the number of wagons loaded or unloaded in 2019, the departure or destination station of which is in the territory of another country. This indicator also includes the use of technical equipment, in particular ramps, which cannot be quantified per number of wagons. In practice, this means that if goods were loaded onto wagons using a ramp or other equipment, their use is represented as the number of wagons loaded or unloaded.
- Use of locomotive depots (G) is represented by the number of operational rolling stocks from 2019. It does not consider non-operational or retired rolling stock, nor does it consider the type of traction. Although the use of the locomotive depot is a matter for whichever operator, it is part of the railway station and should not be neglected. At the same time, it is not only used for vehicle storage but also for other tasks (refueling, minor repairs of rolling stocks and wagons, etc.).
- The technical equipment (H) of the station is represented by the number of wagons from 2019 that have used some of the technical equipment. These are mainly catchment areas and other facilities whose use can be quantified by the number of wagons.
- Transport service lockout (I) is the only negative indicator in the proposed Formula 1. They are quantified using the number of wagons from 2019 that passed through the station at the time of the transport service lockout. It is quantified using the number of

wagons from 2019 that passed through the station and the rail enterprise facilities at the time of the transport service lockout.

The above criteria have different weights or importance for individual railway transport operators. The comparison of both criteria and variants is based on so-called expert estimation, in which experts in the field compare the mutual influences of two factors [46]. The basis of the Saaty method is to write down the individual significance values that will be compared between the alternatives in the evaluation forms in the so-called Saaty decision matrix [47].

When constructing the Saaty decision criterion matrix, the values on the main diagonal will be equal to 1, because the alternatives are compared with themselves here. The other nine values (this will be a 9 × 9 matrix) above the main diagonal determine the subject in the post-comparison. The comparison and weight assignment are usually done by comparing the alternative in the top column with the element in the top row. The values below the main diagonal are written as the inverted values of the individual weights above their main diagonal, according to Formula (1).

$$values\ below\ the\ main\ diagonal = \frac{1}{values\ above\ the\ main\ diagonal} \tag{1}$$

This equation can also be expressed mathematically according to Formula (2):

$$S_{ij} = \frac{1}{S_{ij}} \tag{2}$$

Table 6 shows an example of the Saaty decision matrix according to the pair-wise comparison of criteria.

Table 6. Saaty decision criterion matrix.

Evaluated Criterion	A	B	C	D	E	F	G	H	I
A	1	1/7	3	1/5	1/6	1/8	$\frac{1}{2}$	$\frac{1}{4}$	1
B	7	1	8	1/5	$\frac{1}{2}$	1	5	4	9
C	1/3	1/8	1	1/8	1/9	1/8	1/3	1/8	1/6
D	5	5	8	1	1/5	1/6	7	5	8
E	6	2	9	5	1	2	8	1	7
F	8	1	8	6	$\frac{1}{2}$	1	$\frac{1}{2}$	4	3
G	2	1/5	3	1/7	1/8	2	1	1/7	9
H	4	$\frac{1}{4}$	8	1/5	1	$\frac{1}{4}$	7	1	1/8
I	1	1/9	6	1/8	1/7	1/3	1/9	8	1

The next step is to determine the own vector of the matrix. This is based on the dimensions of the matrix and is calculated according to Formula (3):

$$v_i = \sqrt[n]{a_{i1} * a_{i2} * a_{i3} * a_{i4} * a_{i5} * a_{i6} * a_{i7} * a_{i8} * a_{i9}} \tag{3}$$

where:

v—the own vector of the matrix,

n—the dimension of the matrix (in this case, 9),

a_i—the relevant criterion in the corresponding row.

In Table 7, the decision matrix of Saaty's method is constructed. Using the obtained weights and scores, the order of importance of the evaluated criteria for railway undertakings is created through a weighted sum. In the conditions of the Slovak Republic, three alternatives and nine criteria are sufficient as an example, because these are the most important criteria from the point of view of the analysis. At the same time, as part of other future research, it would be possible to expand them by others, but according to the authors, less important criteria (e.g., use of a mobile workshop, number of cancelled trains, number of trains running as needed, etc.).

Table 7. Decision matrix of Saaty's method.

Evaluated Criterion	Criterion Weight	Importance for Railway Undertakings I.	II.	III.
A	0.03	0.10	0.76	0.14
B	0.17	0.05	0.30	0.65
C	0.02	0.14	0.29	0.57
D	0.18	0.05	0.21	0.74
E	0.27	0.04	0.77	0.19
F	0.17	0.07	0.47	0.47
G	0.06	0.05	0.79	0.16
H	0.07	0.11	0.68	0.21
I	0.04	0.67	0.07	0.26
Weighted sum		0.08	0.50	0.42
Ranking		3.	1.	2.

It is clear from Table 7 that the ZSSK CARGO carrier ranks first. This is followed by the other carriers and, at the end, by the infrastructure manager. A graphical representation of the ranking and the number of points obtained is shown in Figure 3.

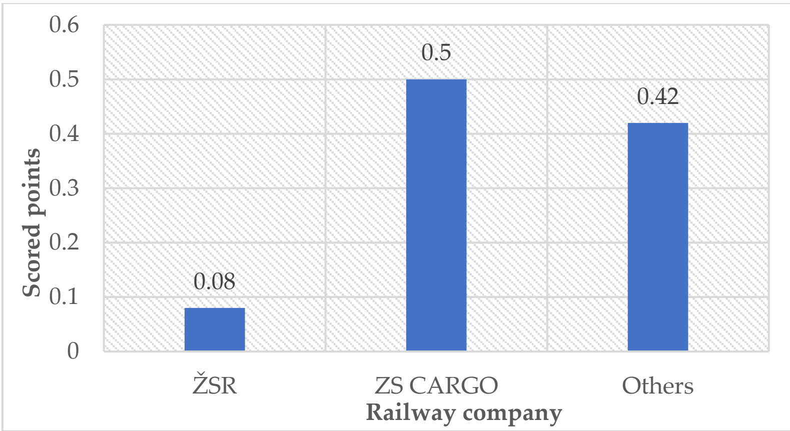

Figure 3. Graphical representation of the railway undertakings evaluation.

Saaty's most accurate method produced the expected results. Since the carriers are the ones who actively use the capacity and facilities of the railway stations, they ranked in the first two places with a difference of 0.08 points. The infrastructure manager came in last because he uses the capacity and facilities to a minimal extent. When using Saaty's method, the validity of the consistency condition is essential, which is conditional on the satisfaction of the following four axioms:

- Inverse—if alternative A is n times preferred to alternative B, then alternative B is 1/n preferred to alternative A; it is a rule of reciprocity expressed by a Formula (4):

$$r_{ij} = \frac{1}{r_{ji}} \tag{4}$$

- Homogeneous—comparison by pairing is significant only if the elements are comparable,
- Dependent—the lower-level comparison depends on the higher-level element,
- Consequential—if a criterion in the hierarchy is changed, a new evaluation for the new hierarchy should be expected [48].

The application of Saaty's method shows that the position of carriers in a liberalized rail market is changing. There is a balancing of power and influence between carriers in the market. This is demonstrated by the presence of carriers at railway stations. Each carrier may demand a different service from the infrastructure manager. As there are relatively many of them, it is necessary for the infrastructure manager's staff to consider the different requirements and adapt the operation to them. The results obtained using the multi-criteria analysis method in the decision-making process should also help to adapt the operation in this way. When providing the capacity of a railway station and its facilities, it is possible to determine the strength and importance of the use of each facility for railway undertakings.

3.2. Proposal for Point Assessment of Railway Stations

The proposal for scoring is based on the results of the findings in the previous chapter. As the highest score was obtained by the carrier ZS CARGO, the scoring needs to be adapted to the needs of the carriers. Figure 4 shows a flowchart with the decision-making procedure for the created methodology. According to it, there will be a total of eight basic steps between the beginning and the end when creating the methodology.

The second step is to determine the number of points based on the positive and negative values of the evaluated criteria. The values can be written into the initial Formula (5).

$$Point\ number = (A * V_A) + (B * V_B) + (C * V_C) + (D * V_D) + (E * V_E) + (F * V_F) + (G * V_G) + (H * V_H) - (I * V_I) \quad (5)$$

where:

A—use of rail weights [wagons/year],
B—use of parking tracks [wagons/year],
C—use of shunting by infrastructure manager [wagons/year],
D—use of private sidings [wagons/year],
E—loading and unloading [wagons/year],
F—import and export [wagons/year],
G—use of locomotive depots [deposited rolling stock/year],
H—technical equipment [wagons/year],
I—transport service lockout [wagons/year],
$V_{A–I}$—weights of the individual value criteria.

The points allocated to an individual station need to be recalculated every year due to the constant changes on the network. The number of stations that can be assessed is also changing because of modernization and reconstruction measures. Figure 5 shows the evolution of the railway station number on the ŽSR network for the period 2015–2020.

The chart in Figure 6 shows that the largest decrease, a total of four railway stations, took place between 2019 and 2020. The year-on-year changes are due to changes in the organization of the transport operations of the ŽSR.

One of the biggest negative consequences of railway station interference is the reduction of railway line section throughput. Another indicator influencing the result of the assessment is the performance of carriers on the ŽSR network, which changes every year, mainly according to the development of traffic and market requirements. Figure 5 quantifies the performance of carriers in freight transport in the years 2015–2020. The performance over the period under review has been relatively stable. A slight decrease started to occur from 2018 onward. The more significant decline in 2020 was due to the global pandemic of COVID-19.

The final step is a proposal to classify the railway station in the appropriate category according to the number of points obtained. The range of scores is variant and is determined by the ratio of the railway station with the maximum number of points (depending on the number of stations on the network, or the number of stations assessed) and the number of variants. The number of variants was determined based on the clarity of the variants in the context of the boundary definition. The advantage is that the number of variants can be adapted to the needs of the infrastructure. The calculation of the score range is performed according to Formula (6).

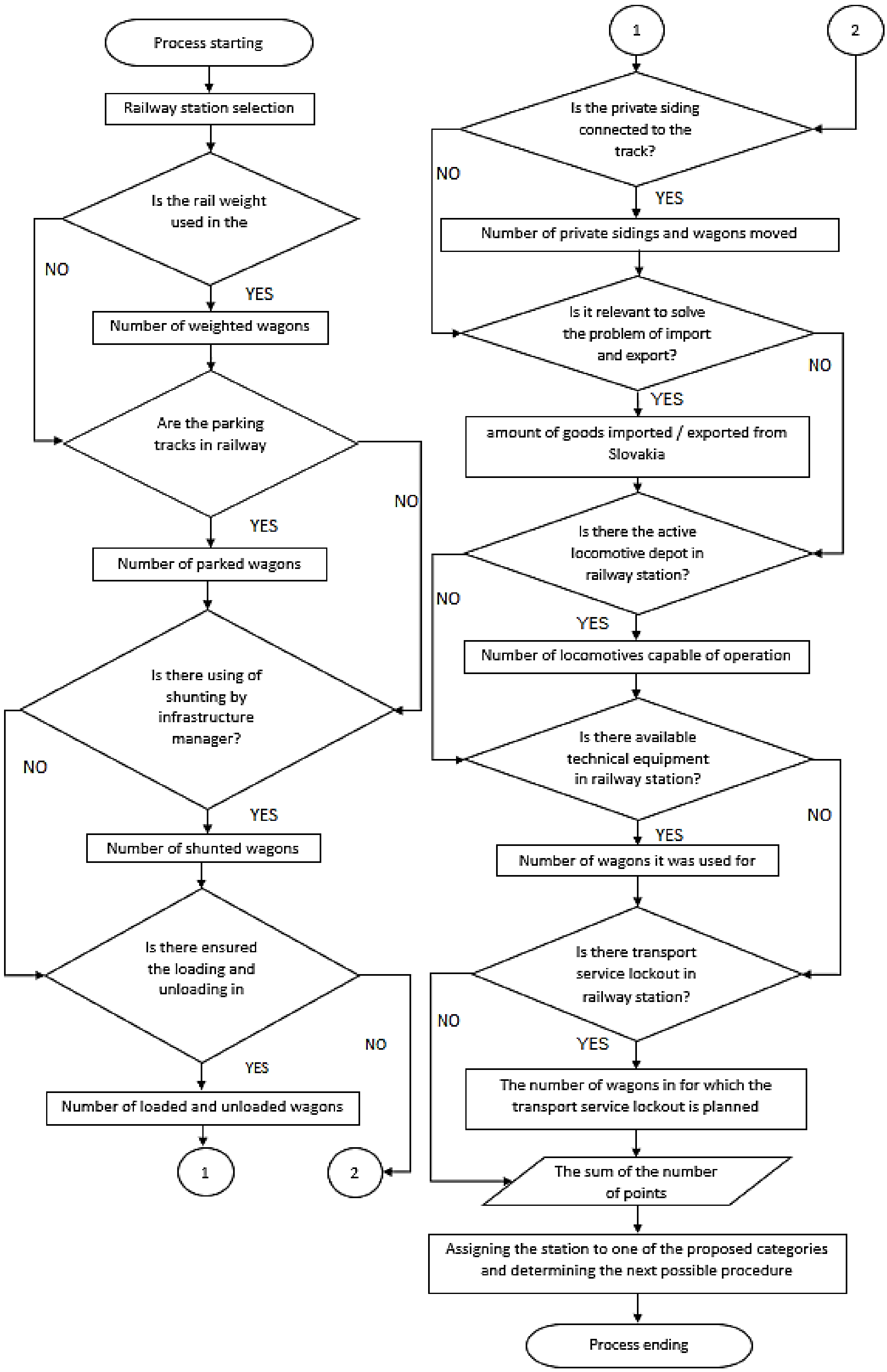

Figure 4. The flowchart of the proposed methodology.

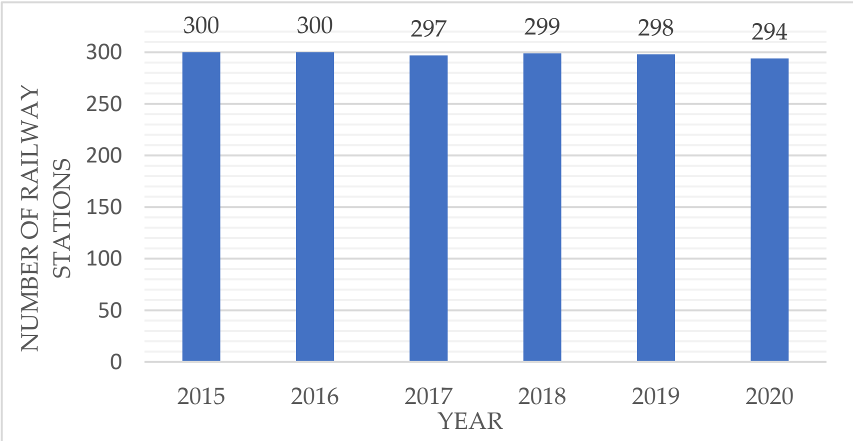

Figure 5. Railway station numbers on the ŽSR network (2015–2020).

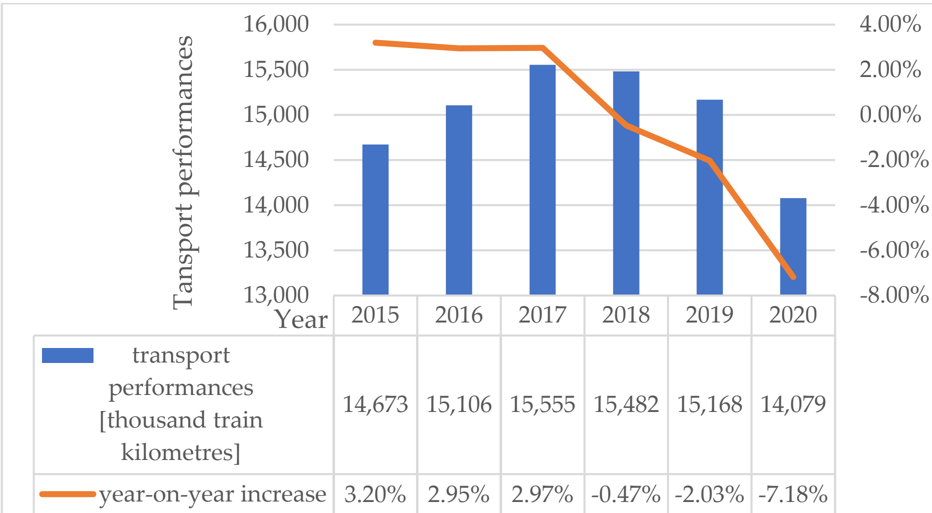

Figure 6. Transport performance decrease of carriers in railway freight transport (2015–2020).

$$Score\ range = \frac{Railway\ station\ with\ maximum\ points}{Number\ of\ variants} \tag{6}$$

This relationship is used to determine the range of scores within three options, which are presented in Table 8.

Table 8. Range of scores of railway stations.

Score Range	Variant	Note
0–1325.4	maintenance mode	the most necessary maintenance at the lowest possible cost
1325.5–2650	no change	focus on the highest
2651–3976.5	reconstruction measures	point value in the formula

A total of four stations are evaluated in the article. The highest scoring station is placed in the numerator of Formula (2). There is only a sample in this paper; if the scores on the whole network are available, the figure in the numerator will change. The resulting values are always rounded up to one decimal place. Once the complete process has been evaluated, it is up to the infrastructure manager to decide how to proceed with the results.

4. Results

After calculating the number of points for individual indicators, railway stations will then be divided according to Table 6 into categories that will determine how to proceed with the railway station. Based on the results, their strengths and weaknesses in the internal environment and threats and opportunities in the external environment will be analyzed.

Based on the data from the above analysis, the calculation of the number of points is carried out in Table 9. The calculation is based on 2019.

Table 9. Point evaluation of railway stations.

Quantity/Number of Points for	Railway Stations							
	Spišská Nová Ves		Strekov		Horné Sŕnie		Záhorská Ves	
	Wagons	Locomotives	Wagons	Locomotives	Wagons	Locomotives	Wagons	Locomotives
A	7.68		0		0		0	
B	3844.21		306.51		28.05		1.02	
C	0	-	0		0		0	
D	35.46		0		4.5		0	
E	45.09		0	-	518.67	-	0	-
F	40.12		0		147.9		0	
G	-	3.9	-		-		-	
H	0	-	0		0		0	
I	0		0		0		0	
Σ	3972.56	3.9	306.51	0	699.12	0	1.02	0
Σ wagons + Σ locomotives	3976.46 = 3976.5		306.51 = 306.6		699.12 = 699.2		1.02 = 1.1	

The summary of the number of points is followed by the classification into one of the categories presented in Table 6 according to relation 2. The classification of the railway stations into one of the categories is in Table 10.

Table 10. Categorization of railway stations.

	Spišská Nová Ves	Strekov	Horné Sŕnie	Záhorská Ves
Number obtained points	3976.5	306.6	699.2	1.1
Score range	2651–3976.5	0–1325.4	0–1325.4	0–1325.4
Variant	Reconstruction measures	maintenance mode	maintenance mode	maintenance mode
Note	Using parking tracks	Using parking tracks	Loading/unloading	Using parking tracks

Depending on the inclusion of one of the variants, measures to support freight transport in the railway station will be presented in the context of the financial and economic demands for the infrastructure manager.

Research question: How will the level of use of railway stations by railway undertakings be reflected?

Answer: We accept hypothesis H0 that the rate of railway station use is higher by carriers and lower by infrastructure managers and reject hypothesis H1 that the rate of railway station use is lower by carriers and higher by infrastructure managers. So, the formulas $CA > IM$ and subsequently $H0 \Rightarrow \neg H1$ are valid.

5. Summary and Discussion

Based on the analysis carried out in the conditions of the Slovak Republic, it can be stated that the examined areas within freight transport are fragmented into several partial problems, which must also be considered. These areas are:

- Legislation-legal norms are taken over from European Union law and implemented into national legislation; however, some articles of the legislative regulation are not valid to this day.
- Charging for access to railway stations in freight transport—the setting of points for the segments used by carriers, the scoring scale based on which carriers are charged

a fee for access to railway stations by the infrastructure manager, prices for access to railway stations in freight transport.

- Transport undertakings with transport service lockout—the need to reassess the necessity of introducing transport service lockout in the context of freight transport potential.
- Equipment of railway stations with rail weights—economic and financial sustainability of rail weights at selected transport points on the ŽSR network.
- Parking tracks in railway stations—non-discriminatory access for all carriers; determination of the maximum time for freight trainsets to be shut down.
- Shunting provided by the infrastructure manager—relevance of providing shunting, reconsideration of charging for the service.
- Connection of railway stations to sidings—unnecessary fees from the infrastructure manager, too high import fees, participation in the maintenance of sidings in the synergistic effect of ŽSR—the state practically does not exist, legislative bureaucracy.
- Re-evaluation of the expediency and limitations of dispatch authorization and optimization of the distribution of employees within the occupancy of individual railway stations.
- Technical equipment of railway stations—optimization of technical equipment of railway stations based on its use in which railway station.
- Submission and issue of wagon consignments—re-evaluation of the number, length, and equipment of general loading and unloading tracks in individual railway stations.
- Border crossing stations—uneven distribution of train flows; border crossing stations with insufficient capacity.
- Locomotive depots—optimal distribution of depots of the ZS CARGO carrier on the ŽSR network.

These 12 characterized partial problems within railway freight transport resulted in the compilation of a methodology for evaluating railway stations from the point of view of freight transport. The methodology deals with the evaluation of railway stations within nine indicators, in which the author tried to cover these twelve partial problems at least partially in their basic intentions. In practice, this means that the methodology will reveal to the infrastructure manager which segment is the highest rated within the given station, and thus the infrastructure manager should take care of improving the current situation.

It was necessary to solve the mentioned problem scientifically, so the relevant method with the most accurate results was the AHP method. Therefore, it can be concluded that the achieved results were expected and are not surprising. The AHP method was not only used as evidence that it is necessary to continue, e.g., in the maintenance of some railway stations and their individual elements, but also to achieve a higher level of understanding of the raised issue, including its scientific concept and a high-quality solution with effective practical application for the infrastructure manager and for the carriers. The proposed methodology for evaluating railway stations from the point of view of freight transport has the following distinguishing features:

- Contains partial steps that follow each other and create a synergistic effect,
- Considers the current needs of railway freight transport—carriers, infrastructure managers, and customers,
- Applicability is broad-spectrum, i.e., it can be used in every country, as far as railway stations of the same nature are concerned,
- Must be repeatable, i.e., it is necessary to recalculate it every year according to the current data on transport flows.

The Spišská Nová Ves railway station, which has the status of a train forming station on the ŽSR network, received a total of 3976.5 points, and according to the resulting tables, the railway station is in the point range of 2651–3976.5 points, which means that the station needs a comprehensive reconstruction. The highest number of points was obtained using parking tracks, which implies that it is necessary to think about the expansion of parking tracks. This is also necessary in terms of the throughput of the railway station and its capacity. As part of the complex reconstruction, it is necessary to replace, e.g., station security equipment, switches, or other equipment on the track.

Another example is the intermediate railway station at Strekov. It received a total of 306.6 points in the evaluation. According to the resulting table, it falls into the range of 0–1325.4 points, which means that the railway station should be left in maintenance mode. It is necessary for the manager to focus on the bottlenecks of the railway station in the field of freight transport. In this case, it is the number of parking tracks. An example of a border crossing station is the Horné Sŕnie railway station. This train station is in the point range of 0–1325.4 points with a total gain of 699.2 points, which means that the train station needs to be kept in maintenance mode. In practice, this means that the investments that the infrastructure manager puts into the station will either have a very long (several tens of years) or no return. Therefore, it is important to carefully assess whether it is necessary to invest in the segment that has the highest number of points. In this case, it is the loading and unloading segment.

The last example is the Záhorská Ves transport station located on the railway line with simplified transport management in Zohor–Záhorská Ves. This transport company received only 1.1 points in 2019, based on which we place it in the point range of 0–1325.4 points. This point spread means that freight transport is carried out to a minimum extent by the transport company. Since passenger transport has been stopped on the line since December 2019, under Act 513/2009 Coll., the infrastructure manager is obliged to keep the railway line passable. In the context of freight transport, it is not good to invest in new equipment because not only the return but also the utilization is minimal.

The resulting calculated values show that the differences between them are relatively high. The authors wanted to point out what inequalities exist in the case of the use of individual station types on the Slovak Railways network and to assess the possibility of their quantification. Therefore, different station types were deliberately selected in the context of Table 2.

The methodology in no way solves all the problems of railway freight transport mentioned here; these can be the subject of further investigation. A possible limitation of our research may be the evaluation of different railway freight stations instead of comparing two "significantly" identical stations. As part of future work, it would be appropriate to focus on measures related to railway freight stations that we did not address in our research (for example, the decision to leave the station, relocate it, establish a new one, or split it). Another suitable step would be to propose an algorithm instead of hypotheses and thus verify the usability of railway freight stations in large, medium, and small cities, which by their nature are among the important ones. Our research also considers the involvement and utilization of private sidings at railway stations. Again, based on this paper, this would be an extension of our research that could focus on better utilization of private sidings from an economic perspective. The return through the CEA financial analysis shows better results, and these could be applied in this environment after reassessing the attractiveness of railway stations from the freight transport point of view in Slovakia.

6. Conclusions

The objective of the article from a broader point of view was to point out the development of the quality of railway infrastructure in cities, with an emphasis on railway freight transport. An important element of the railway infrastructure is the railway station, which must ensure the maximum efficiency of the railway operation. Therefore, it is necessary to correctly set the method of railway station evaluation. The main objective of the contribution was to create a universal methodology for evaluating railway stations using the AHP method from a freight transport point of view. The mentioned methodology aims to improve the quality of railway freight transport qualitatively and quantitatively in Slovakia with the contribution of the infrastructure manager and carriers. As part of the methodology, a complex methodological procedure was proposed using the Saaty method, evaluated criteria and subjects, and the decision matrix of the Saaty method. Subsequently, two formulas were proposed to determine the point evaluation and its range. A hypothesis (research question) was also formed, which was subsequently accepted. As part of the practical application, the works of four railway stations were evaluated.

The author's intention is to improve the quality of the provided services and processes of railway freight transport, which should lead to an increase in transport performance and a more efficient and faster transfer of goods from road to railway transport. A significant contribution of the paper to the professional public is to present and practically apply a new methodology for the evaluation of freight railway stations. For freight carriers, logistics operators, and shareholders, it will have the most significant benefit in that it will help them in planning transport and transport performance, especially the scope of transport, as they will have a better overview of the technical equipment of individual stations, and thus it will be possible to include them in particular categories more efficiently. In a broader sense, the practical contribution of the mentioned research and its results will contribute to more conceptual railway freight transport planning, which will also benefit passenger transport at all levels and, ultimately, the sustainable development of railways in the city. The proposal contributes to the enrichment of science in the field of transport processes, including its useful practical application.

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