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Estimation of Transport Potential in Regional Rail Passenger Transport by Using the Innovative Mathematical-Statistical Gravity Approach

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Abstract: Planning the range of transport services in the selected geographical area is particularly relevant in the context of developing integrated transport systems. The aim is to build a sustainable public passenger transport system as an alternative to individual transport. Realizing quality and efficient transport services is a comprehensive process, though there are currently no applicable principles of its proposal and creation in terms of creating the appropriate range of railway infrastructure. The paper presents the general research results focused on solving the problems of transport services in the regional passenger railway transport. The gravity model allows the study of the dependence between the population in the adjacent area, the availability of stops and the length of the transport line. A part of the research is to adjust the inputs of this model to more accurately determine the range of railway infrastructure. Based on the research of the palette of railway lines, the necessary capacity of infrastructure in terms of ensuring the required number of trains in peak hours is adjusted. The output is a proposal of the session to the calculation of transport potential and subsequently its practical application. Finally, based on its resulting values, it is possible to adjust the transport concept to set up a more efficient and higher quality timetable.

Keywords: transportation potential; gravity method; railway line; transport concept

1. Introduction

Promoting more sustainable public transport to alleviate the problems resulting from the excessive use of the individual car transportation in most metropolitan areas (congestion, pollution, noise, etc.) as well in regions, is one of the main concerns of transportation planning. The support of public passenger transport and rail passenger transport is actually very important and necessary. The European Union in its transport policy forces this issue, while the most important document is Transport White paper 2011 [1]. Passenger trains operation should be realized on each railway line or transport route and should be reinstated in those routes where it was cancelled in the past but nowadays there is sufficient potential. The main advantages of the rail transport system are its high transport capacity and environmental friendliness. Therefore, the rail passenger transport must be a key element of the passenger transport system. In addition, integrated transport systems development brings new requirements for transport systems functions in the service of the selected area.

Opening the railway market for services in the EU requires the implementation of the interoperability conditions, to integrate railway systems in its complexity and enable the movement of trains without unnecessary restrictions arising from the technical and organizational differences in these systems [2]. Railway systems consist of the infrastructure, as it has a track, vehicle [3] and traction

power system [4], rail vehicles and the operational level. Due to the huge cost in the construction, operation and maintenance, the improvement of traffic efficiency is desired. Allowing access of interoperable trains to interoperable networks is preceded by activities that allow the assessment of the fulfilment of all basic conditions in terms of technical compatibility, performance, and organization of the trains. In order to improve public transport, developing appropriate infrastructure range as well connection is necessary. These measures should take into account the different characteristics of a service, which concern various aspects such as service planning, reliability, connections comfort and so on. Transit service quality, in fact, depends on the quality levels of the factors describing the service. Given the multiplicity of these factors, it is very difficult to preliminarily select the factors to be considered for transportation service quality [5]. Here is a need to consider the railway transport as a key transport system. Timetabling is based mainly on current transport needs and passenger frequencies. It is rare to take into account the transport potential that individual railway lines offer from the viewpoint of regional rail passenger transport [6].

Rail passenger transport problems are addressed by a large number of transport experts and scientists. Our target is focused to research a relationship between transport planning and desired transport services quality in the frame of sustainability transport system. For example authors Eboli and Mazzulla in the study “Relationships between rail passengers’ satisfaction and service quality: a framework for identifying key service factors” [7] propose a methodology aimed at establishing the importance of the various characteristics of a transportation service for the overall service quality, in order to identify the key factors for the users of services.

Public transport, in the concept of quality of transport service, is more than just a social service for those who have no other option but its aim is to achieve an overall transport accessibility of the region, so that public transport represents an attractive alternative to individual transport [8]. Qipeng et al. in their empirical study, Synergetic Effect and Spatial-Temporal Evolution of Railway Transportation in Sustainable Development of Trade [9], describe the synergy effect in railway transportation in the context of the sustainable transport system. The authors explained basic principles of the railway passenger transport management, position of railway passenger transport and proposed measures to make the railway passenger transport system more effective and make the entire transport system based on a liberalized transport market more attractive for travelling. Banister [10], in his scientific publication “The sustainable mobility paradigm”, introduces measures for improving transport mobility and key elements of sustainable mobility.

The concentration on a wide range of problems in transport planning is focused on, among others, sustainable transport [11–15], modeling and simulation [16,17] and economy and competitiveness in transport [18–26] which creates the background outcome for future research.

With regard to the rational planning of public transport and the final volume of funds for compensation payments, these resources cannot be spent inefficiently on the transportation of single individuals, as there will not be the resources required to ensure satisfactory transport in contexts with a much higher demand [8]. More detailed methodology for transport quality assessment in regional transport is published in [5,27]. To ensure of connection quality is very important for timetabling process [28,29].

The infrastructure planning is connected with capacity issues. More details of the railway infrastructure capacity estimation are in [30,31]. The regions need a master plan, design and capacity analysis of the future network timetable and to track infrastructure with focus on the methods and results for capacity estimation. The methods used and results reported for the capacity analysis of the network timetable until the robustness analysis in the scope of the stress test simulations are described in detail in order to identify the critical issues [32].

The original approach consisting of a periodic network timetable design, queuing models for the estimation of the waiting probability and queue length for the purpose of timetabling and estimation of the operations quality respectively, as well as multiple stochastic simulations are explained and

the consistency of the recent stress test simulations are examined [32]. The principles of periodic timetabling are developed in studies [33–36].

The question is how to set up the appropriate number of trains on the infrastructure to serve the needs of inhabitants in specific regions.

Eduard Lill presented, in 1891 in Vienna [37], elements of a law of travel and the statistical testing of it with empirical data from the Austro-Hungarian Empire in which he anticipates much in current geographic models of spatial interaction. Because of the increasing importance of Lill's ideas, it was thought that a translation of his Law of Travel and Its Application to Rail Traffic would be appropriate [38]. Lill denoted his observations as a law of Nature analogous to Newton's law of gravitation in physics. However, it has a fundamentally different theoretical approach. Gravity models for the prediction of trip distribution have been developed and applied by many authors, a gravity model with a double-constrained iteration for trip generation and attraction at each zone. These types of models are still used for aggregated trip estimation [39]. Horbachov and Svichynskyi [37] noted that more realistic trip length distributions similar to the "classic gravity model" are obtained when using the "reduced gravity model" and "random matrix" model. The result of the "Random Matrix" model is especially important as it refutes the determinism of the trip distribution process.

Janos and Krizik in their derived gravity model [8] find out which transport sessions (relations) have the highest theoretical travel potential generally and what the public transport daily offer is, which is provided in relations with a "similar" significance. This extensive gravity model for the Usti nad Labem Region (Czech Republic) is based on "Lill's travel law" [8]:

$$v_{ij} = k \cdot \frac{Q_i \cdot Z_j}{w_{ij}} \quad (1)$$

where:

- v_{ij} passenger flow between i -th and j -th places;
- k gravity constant;
- Q_i source/origin potential of i -th place;
- Z_j destination potential of j -th place;
- w_{ij} deterrence function.

Within the configuration of the model, all the towns in the region with more than 5000 inhabitants were taken into consideration, including the usual destinations in regular commuting to neighboring regions and the capital city (additional targets). The basis for the model processing was the Census data, while the comparison of travel times was based on timetables that were available at that time, as well as a publicly available route planner (for center–center relations). This methodology considered the travel time by public transport also with connections showing regularity or "usual" travel time. For reaching a public transport station, a surcharge of 20 min was generally applied. Average waiting time for a service/connection has been neglected. Here it is necessary to take into account the correlation between the attractiveness of the two monitored areas (i, j) and the transport distance. Higher transport flows can be expected (higher number of journeys) with short distance. The model of Janos and Krizik also took into account the superiority of the territorial units. The model can effectively capture significant transport relationships, with which could be designed direct links without transfer needs. In the case of a proportional comparison, the constant k can be omitted. The result is a numerical value that expresses the "strength" of the transport flow after recalculation. [4]

Other research and explorations specialized on empirical models in transport planning explain gravity methods and models used in passenger transport. The output of these models is the proportional comparison of the significance of passenger flows, typically associated with the theoretical calculation of the modal split. From the gravity model, when taking into consideration the modal split, it is shown how public transport is successful in individual contexts. For example, the authors' research team applied Lill's gravity model in publication [38]. This model develops the optimum number of return

journeys of all types of public passenger transport between the two selected tariff points, considering the number of inhabitants of these transport points and the distance between them. The presented solution considers a wider approach to ensuring transportation services linked to railway infrastructure, while the factors that influenced the transportation potential were not researched in detail.

2. Materials and Methods

At present, there is no available appropriate methodology for optimizing the generally applicable setting of the transport service system on individual rail transport lines. Therefore, the objective of this paper is a proposal to determine the transport potential on regional transport relations, which is based on scientific mathematical-statistical principles. Subsequently, the calculation methodology is applied to selected transport lines according to the Slovakian railways network, where the Railways of the Slovak Republic (ZSR) the role of infrastructure manager plays.

The methodological basis is the current gravitational model used for the transport relationships estimation (especially “Lill’s travel law”, i.e., see in [8,39,40]), which is based on the assumption that the transport relationship between settlements increases with their size and decreases with transport resistance (represented by time or geographical distance). This model neglects seasonality, also the assessment of the availability of a stop in railway transport and bus transport as well as the settlement and administrative hierarchy. The gravitational models presented so far have not been able to answer the question that is key to determining the transport potential. Several prognoses and analyses show that the practical impact of this model is very low and the resulting values are irrelevant in many cases. However, known gravity models were an inspiration for developing the adapted formula that is considered as a new progressive gravitational approach.

The goal of this paper is to define and determine the transportation potential, as an important part of the sustainable railway passenger transport. The calculated passenger flow is directly proportional to the number of inhabitants of both transport points, the K_p coefficient and the inversely proportional distance of these traffic points. However, there are a lot of unexplored theoretical and practical principles in the field of planning, organizing and timetabling a railway passenger transport system.

A comprehensive proposal for a methodology for assessing the potential of rail infrastructure for providing transport services in the integrated transport system consists of several partial proposals that are closely related and interconnected. The individual steps are described by a comprehensive heuristic procedure, developed by the authors.

This heuristic procedure for providing a transportation service with the link to the extent of railway infrastructure, in principle, consists of these steps:

1. Determination of actual transport needs.
2. Determination of current travel motives.
3. Classification of the transport service type.
4. Definition of factors affecting transport services.
5. Determination of transport potential.
6. Determination of the range of railway infrastructure.
7. Proposal for final timetable standards.
8. Final timetable construction.

The partial objective of the proposal will be a new characterization and classification of transportation services provided by railway transport according to various criteria, as well as a definition of the factors affecting transport services. However, it is essential to take into account current transport needs and current travel motives. Subsequently, a methodology for determination of the transport potential will be proposed within individual aspects of the transport service, which can be determined at any selected transport link. Authors presented the more detailed developed heuristic methodology. The difference with the Janos approach in the study [8] is in the estimating of

the K_p coefficient as a representative indicator for transportation potential in the adapted model and incorporating the travel times.

An objection of this paper is the crucial part of this procedure, to define the railway infrastructure and its optimal range as a necessary element for carrying out the required transport service. After considering this proposal there is possibility to develop other transportation measurements, i.e., design of standards within the individual transportation service systems. Although, the measurements are planned in the scope of the functioning integrated transport systems (in whole areas).

3. Results

3.1. Transport Potential Based Formula

The main idea of establishing potential within the regional transport segment is to propose a methodology that takes into account selected factors influencing this potential. Although, not all factors can be expressed exactly or numerically. The ideal case is to propose an attitude to calculate the transport potential, and the input data should be the values of individual factors. The resulting value of the transport potential is expressed by the so-called transport potential coefficient (K_p). The main objective is to determine the total K_p value as directly proportional to the existing transport potential. Number of K_p indicates higher of potential on the selected rail line (session) and the need for a better rail transport operational concept (presented as a connection offer for passengers in the timetable).

The transport potential within regional rail transport services depends on several factors. For the purposes of the proposed methodology, factors specified for rail passenger transport are developed, partially in the paper [41]. These are:

- Number of inhabitants belonging to the track line section under review.
- Momentum of the population.
- Transport distance.
- Availability of the railway station and stop.
- Overlapping with road.
- Continuity of the assessed section to other railway lines.
- The monitored area's attractiveness.

Therefore, it is important to consider only those factors whose impact on transport potential is most pronounced and whose values are beyond doubt. Logically, the 'number of inhabitants belonging to the track line section under review', 'transport distance of the session' and 'availability of the railway station and stop' expressed by the distance of the railway station or stop from the settlement center, might be factors in the transport segment under review. These factors have the greatest impact on transport potential. However, the impact of other factors may also be significant, but given the relatively complex exact expression, as mentioned above, these factors won't be taken into account in the conception of the formula. In addition, the transport distances should be considered clearly, as it is very important to take the principle resulting from the gravitation model into account; the effect of the distance between two settlements (the closer these settlements are), the higher the attractiveness between them. If the transport potential is represented by an index for a transportation session on the route with n settlements, then A_n is the number of inhabitants of the studied area (settlement) n in thousands. For the settlement n , the access to railway stations or stops given in km as distance from the municipality center or geographic center of adjacent settlement, represents D_n . The resulting equation for the calculation of the transport potential K_p for regional transport is:

$$K_p = \frac{\sum_1^n \frac{A_n}{D_n}}{L} \quad (2)$$

Construction of the formula was based on the general mathematical principles of direct and indirect proportionality, i.e., the fact that the direct proportional values affecting total transport potential

(in this case the population) are located in the formula's numerator and the inverse proportional values (in this case station or stop) in the formula's denominator. The proportion of these factors is subsequently carried out in all settlements in stations and stops on the monitored transport route. The resulting value for the transport session will be the sum of all shares, which will be divided subsequently by the transport distance on the monitored transport session. This is needed in order to make it clear and understandable whether the given potential is reached on a transport session along, e.g., 10 km or 100 km, which is a significant difference.

3.2. Assignment of the Resulting Value of the Range of Transport Services

After calculating the final value of the transport potential K_p , it is very important to be able to transform this value into at least the approximate number of trains and offered seats in trains that should be operated on the researched transport session. However, it would be much more accurate to at least determine the approximate frequency of daily passengers on a working day and over the weekend, based on the calculated transport potential. On this basis, it would be appropriate to determine the expected frequencies of passengers on the monitored transport session and therefore the optimum number of trains, as well as the maximum seating capacity. However, transforming the resulting value of K_p to determine transport flows is a relatively complex process. There is also the possibility of diverting from the current frequencies of passengers on the individual line sections, but these values may also be distorted, as they are strongly influenced by the current range of traffic.

Finally, after considering the various ways to best realize this transformation, the following approach was taken as follows:

- The scale will be determined based on the calculation of the resulting value of K_p on the selected 30 transport sessions. Subsequently, assigning the resulting values to the different ranges of traffic, which will be marked with Roman numerals (I–X), including determining the optimum number of trains and the optimal number of seats;
- The sample of 30 transport sessions contains all transport sessions (track sections between individual centers) on Slovak railway networks in the Zilina and Trencin regions (with the exception of the Trencianska Tepla–Trencianske Teplice railway line). In the next step railway lines in western part of Slovakia (Bratislava–Trnava, Bratislava–Galanta, Bratislava–Kvetoslavov, Kutý–Skalica, Zohor–Zahorska Ves, Zohor–Plavecky Mikulas, Jablonica–Brezova pod Bradlom and Zbehy–Radosina), in central Slovakia (Breznicka–Katarinska Huta) and in eastern Slovakia (Plesivec–Slavosovce, Kosice–Kechnec, and Banovce nad Ondavou–Velke Kapusany) were analyzed. This selection covers transport sessions with different ranges of traffic: extremely high, extremely low and medium high transport potential are expected to make the subsequent data as relevant as possible;
- The following scale shall be based on the resulting K_p values on the analyzed transport lines, and the standard deviation shall be calculated from each of the resulting K_p values as a standard deviation:

$$\sigma = \sqrt{\frac{1}{N} \sum_{i=1}^N (x_i - \bar{x})^2} \quad (3)$$

The number of monitored transport sessions is N for each session potential x_i and the average value of K_p is \bar{x} .

- After the calculation, the individual ranges of the traffic services are determined by deducting the standard deviation (or its half value) from the average until the zero value is reached and then adding the same number of particular values, which can be express by:

$$(\dots; \bar{x} - 3\sigma; \bar{x} - 2\sigma; \bar{x} - \sigma; \bar{x} + \sigma; \bar{x} + 2\sigma; \bar{x} + 3\sigma; \dots) \quad (4)$$

- In the research 10 ranges of traffic service with 10 equally wide intervals were established, so it is preferable to consider half of the standard deviation, using this formula:

$$\left(\dots; \bar{x} - 3\frac{\delta}{2}; \bar{x} - 2\frac{\delta}{2}; \bar{x} - \frac{\delta}{2}; \bar{x} + \frac{\delta}{2}; \bar{x} + 2\frac{\delta}{2}; \bar{x} + 3\frac{\delta}{2}; \dots \right) \quad (5)$$

- However, after this step, it may be necessary to modify the said interval width, as it is very important to adjust the scale in such a way that it actually corresponds to the individual values that can be achieved on each transport route;
- Calculations of the transport potential K_p are given in Table 1, in which the main characteristics of the transport session (line type, number of line tracks, line lengths, as well as subsequent calculations of arithmetic mean and standard deviation) are expressed. The sessions are listed from the highest value to the lowest value of K_p potential.

Table 1. Determining K_p value on selected transport sessions on ZSR network.

Transport Session	Railway Line Type	Tracks Number of Line	Railway Line Length (km)	Transport Potential Coefficient K_p	Range of Transportation Services
Bratislava–Trnava	Main	2	46	2501.94	IX
Bratislava–Kvetoslavov	Main	1	22	2369.93	VIII
Cadca–Makov	Regional	1	26	2331.19	VIII
Kralovany–Trstena	Regional	1	56	1959.70	VII
Trencianska Tepla–Horne Srnie	Regional	1	8	1821.07	VII
Chynorany–Prievidza	Main	1	34	1814.27	VII
Cadca–Zwardon	Main	1	22	1778.25	VI
Zilina–Rajec	Regional	1	21	1739.25	VI
Bratislava–Galanta	Main	2	49	1445.98	V
Trencin–Puchov	Main	2	35	1421.58	V
Zilina–Liptovsky Mikulas	Main	2	83	1376.77	IV
Zilina–Cadca	Main	2	30	1341.99	IV
Prievidza–Nitrianske Pravno	Regional	1	11	1265.99	IV
Trencin–Chynorany	Main	1	49	1111.57	III
Nemsova–Lednicke Rovne	Regional	1	17	1103.28	III
Puchov–Zilina	Main	2	44	1070.74	III
Kuty–Skalica na Slovensku	Regional	1	26	1056.32	III
Jablonica–Brezova pod Bradlom	Regional	1	12	912.26	II
Zohor–Zahorska Ves	Regional	1	14	882.75	II
Puchov–Horni Lidec	Main	2	28	815.21	II
Martin–Horna Stubna	Main	2	32	811.38	II
Prievidza–Horna Stubna	Regional	1	37	783.20	II
Zbehy–Radosina	Regional	1	20	777.65	II
Banovce n/O–Velke Kapusany	Regional	1	26	729.84	II
Kosice–Kechnec	Main	1	28	725.81	II

Table 1. Cont.

Transport Session	Railway Line Type	Tracks Number of Line	Railway Line Length (km)	Transport Potential Coefficient K_p	Range of Transportation Services
Nove Mesto n/V–Myjava	Regional	1	36	705.34	II
Zohor–Plavecky Mikulas	Regional	1	35	666.51	I
Plesivec–Slavosovce	Regional	1	24	616.03	I
Breznicka–Katarinska Huta	Regional	1	10	577.09	I
Myjava–Velka n/V	Regional	1	14	290.56	I
Average value K_p			1226.78		
Standard deviation from individual values δ			583.482		
Half of the standard deviation $\delta/2$			291.741		

Source: (authors).

The calculated values show that the highest potential is expected on transport routes in the surrounding area of Bratislava capital (Bratislava–Trnava and Bratislava–Kvetoslavov), the lowest potential is reached on lines where regular passenger traffic is currently stopped (Kosice–Kechnec, Zohor–Plavecky Mikulas, Plesivec–Slavosovce, Breznicka–Katarinska Huta). Relatively high transport potential K_p is calculated for the lines Cadca–Makov, Kralovany–Trstena and Trencianska Tepla–Horne Srnie, mainly due to the densely populated settlements close to the railway line and the relatively convenient accessibility. On the contrary, higher transport potential at the main line section Bratislava–Galanta was expected, but this value was slightly lower, mainly due to the poor availability of some stops. It is also surprising, that low transport potential was reached on the cross-border line Nove Mesto nad Vahom–Velka nad Velickou, mainly due to the low population of most municipalities. Due to a turning point of passenger flows in the Myjava station, the line was divided into two sections for the purposes of the next analyses. However, in certain cases, the line links two district towns and at the same time the greater part of the line is routed parallel with the road; the current transportation service is of a higher range than it should be according to the calculated K_p value. After determining all K_p values, mean value, standard deviation and its half value, then is possible to determine the width of the intervals for the proposed service ranges as shown below:

$$\left(\dots; \bar{x} - 3\frac{\delta}{2}; \bar{x} - 2\frac{\delta}{2}; \bar{x} - \frac{\delta}{2}; \bar{x} + \frac{\delta}{2}; \bar{x} + 2\frac{\delta}{2}; \bar{x} + 3\frac{\delta}{2}; \dots \right) \quad (6)$$

In practice, this means adding and subtracting multiples of $\delta/2$ (291.741) from / to the average value of \bar{x} (1226.78) until the zero value is reached in the case of a countdown and the value adjacent to the range of traffic service X in case of adding. In the case of strict adherence to the above procedure, the interval widths of the resulting K_p value for individual ranges of transportation service would be as is introduced in the Table 2.

Table 2. Width of created intervals with strict adherence to the above procedure.

Range of Transportation Service	Interval Width
I	0–351.55
II	351.56–643.29
III	643.30–935.03
IV	935.04–1226.77
V	1226.78–1518.51
VI	1518.52–1810.25
VII	1810.26–2101.99
VIII	2102.00–2393.74
IX	2393.75–2685.48
X	2685.49 and more

Source: (authors).

However, as the distribution of the individual K_p values is not very uniform and the lowest value is up to 291.741, it was based on scientific and expert opinions established to adjust the specified interval width with method shown in Table 3.

Table 3. Adjusted interval width.

Range of Transportation Service	Interval Width
I	0–700
II	701–1000
III	1001–1200
IV	1201–1400
V	1401–1600
VI	1601–1800
VII	1801–2000
VIII	2001–2500
IX	2501–3000
X	3001 and more

Source: (authors).

- Following the width determination of the resulting K_p intervals for each range of service, the recommended daily number of pairs of all links, the recommended daily capacity, and the total number of all seats in all vehicles on session links shall be assigned to these ranges. The recommended capacity interval for individual ranges of transportation services is relatively wide, since it is necessary to consider individual extreme values of capacity of individual links. In fact, it is possible that one regional link can have a capacity of 50 seats (appropriate for motor unit) and another regional link can have a capacity of 480 seats (appropriate for a train set of wagons);
- For segments of regional and suburban transport services, recommended regional values are introduced in the Table 4; it is expressed in specified optimal number of train pairs as well optimal number of seats on all vehicles operated on the transportation session.

Table 4. Suggested parameters of transportation service ranges according to the transport potential.

Range of Transportation Service	Transport Potential Range K_p	Optimal Number of Train Pairs in Both Directions	Optimal Number of Seats for all Lines in Both Directions
I	0–700	4	up to 500 seats
II	701–1000	5–6	250–2700
III	1001–1200	7–10	350–4500
IV	1201–1400	11–15	550–6800
V	1401–1600	16–20	800–9000
VI	1601–1800	21–25	1050–11,300
VII	1801–2000	26–30	1300–13,500
VIII	2001–2500	31–39	1600–17,600
IX	2501–3000	40–49	2000–22,100
X	3001 and more	50 and more	2500 and more

Source: (authors).

As a statistical-mathematical methodology supported by a new innovative gravity methodology is declared the mentioned procedure for determining range of transportation services. However, the recommended capacity of services (number of trains, number of seats) based on the calculated K_p value cannot be considered accurately. That makes it necessary to navigate in each case and under all circumstances. It should be stressed that this is the recommended range of services based on explicit calculations taking into account the population, availability of the railway station (stops) and transport distance. A number of other factors also affect transport services in the regional and suburban transport segment, which must be considered and subsequently assessed to determine whether or not it is necessary to increase or decrease the level of the recommended range of traffic services. For the analysis of the other above-mentioned factors, it is necessary to examine also the following:

- Whether the region is attractive for tourism and whether there are tourist attractions (recreational, spa, sports, cultural, commercial, social, or other) close to the railway line;
- Whether most jobs, schools, universities, offices, etc. are concentrated in the region (from these centers it is necessary to ensure optimal transportation service);
- Whether the railway line is in direct parallel with the road;
- Whether the transport route is part of a railway line which is of important transit significance or only of local significance and the railway line is terminated at the head station;
- What is the general transport momentum trend in the region under review (but this data is rarely available).

These factors need to be considered for estimating the resulting level of transportation services. There is space for deeper research of a more comprehensive nature; the researcher team publishes the wider view on other aspects of the methodology.

4. Discussion and Conclusions

Increasing population mobility and the current trend of creating integrated passenger transport systems are opportunities for finding new possibilities to develop public passenger transport on particular railway lines, where the passenger transport service is not optimal or is cancelled. The efficiency and speed of transportation, its impact on the environment and energy consumption significantly affect the sustainable development of the area and the development of society.

The issue of sustainable regional rail transport could be addressed from several perspectives and consists of several partial steps and proposals, which are closely related and follow each other. The basis of the presented solution is the adaptation of the existing gravitational method, specifically Lill's gravity model. The various mutations of the model that have been developed and presented by several authors cannot adequately respond to the need to determine the adequate number of connections on the examined session. The solution proposes a new formulation of Lill's law including

the definition of individual input values, which reflects the need for use in traffic planning in practice. The paper presents a procedure for determining the transportation potential of the examined session as a part of the overall heuristic procedure for determining the scope of the transport infrastructure and the operational concept. The potential is determined in a new way as a coefficient based on the knowledge of the size of all settlements on the examined route, as well as of the unconventional location of railway stops. The transportation potential of a regional session observed in attraction zone is directly proportional to the sum of the shares of the number of inhabitants and the availability of individual tariff points on this transportation session and is indirectly proportional to the length of the transportation session.

The procedure for determining the hierarchy with respect to the scope of a traffic service can be considered as a statistical-mathematical method supported by an innovative gravitational method. The purpose of the proposal is to elucidate a very important step towards a new characterization and classification of transportation services provided by rail transport according to various criteria, as well as a definition of the factors affecting traffic service. In this step, using scientific methods, ten ranges of transportation services on the line were determined. The proposed intention to assess the necessary range of transport connections (trains) on regional transport lines is judged from the point of view of the identified factors significantly affecting the demand for regional rail transport. The result is setting up the transport concept in selected transport sessions while the railway system is considered as a backbone in the integrated transport system in a region. In the case that the railway line in terms of capacity is not able to accept the specified range of traffic, some measures must be taken to increase the capacity of the railway line so that it can fulfil the required role in the transport system. However, the overall process is quite complex and it was not possible to include all sub-steps in this contribution. Further procedures and proposals within the methodology will be the aim for further research. The practical application of the proposed methodology, in principle, could significantly contribute to the efficiency of timetabling processes, transport service tendering processes and generally to the development of an optimal traffic services concept and to the assessment of the justness of the use of regional rail lines in integrated transport systems.

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