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Horizons of Railway Transport – Determinants of the development of the railway system in the context of the society-wide assessment of investments in railway infrastructure and public passenger transport

Measuring the Accessibility of the Railway Network with the Possibilities of Increasing the Attractiveness of Railway Transport

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Abstract

The accessibility of the railway network represents an important factor in the choice of public transport compared to individual transport. Rail transport should represent the basic framework of public transport, while associated forms of transport such as cycling or walking would complement it. Acceptable accessibility and optimization of spatial as well as temporal accessibility is an important decision element in the choice of public transport. The time value plays an important role in analysing the use of public transport. In this article we deal with the specific methods for accessibility evaluation that are based on analysis of municipalities and correct location of railway stations, stops as well as transfer terminals. The analysis took into account isochronous maps of the analysed area of selected cities within the Czech Republic and the Slovak Republic. Selected methods are applied on different railway lines according to their purpose, because accessibility of regional and long-haul trains should be evaluated differently. For the given calculation of the individual time availability areas, the number of inhabitants who have access to rail transport was determined, while the average number of inhabitants in one housing unit served as an indicator. The potential of passengers in long-distance trains for use in public transport was set as result to restore and increase the competitiveness of rail transport.

Keywords: accessibility, railway transport, time availability, passenger transport

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1. Introduction

As a result of mounting concerns over the adverse ecological and socio-economic effects of mobility systems dominated by individual motorized transport, metropolitan areas worldwide have expressed a renewed interest in the role of public transport (Caset et al. 2018). Accessibility is a widely used concept in transportation planning and research (Páez et al. 2020). The population mobility is seen in every day's need to travel to school, to work, for shopping, for leisure, etc. by every available transport mode that enables movement (Mašek et al. 2017). Accessibility is an important factor influencing the choice of a suitable mode of transport. It can be interpreted in two ways: accessibility to public transport (how to access public transport services) and accessibility by public transport (how to reach opportunities by public transport). For longer distances, passengers most often prefer individual car transport, suburban bus transport, or public transport. The long travel distance of the site and the surrounding areas affects the rail transit service level (Gašparík et al. 2017). In some cases, it is possible to combine different modes of transport that help to transport passengers living at a greater distance from the railway station or stop or passengers living in a municipality (city) where the railway station or stop is not located. Consequently, it is necessary to optimize the schedule of the train coordination to meet the demand of passengers. First-and-last-mile accessibility in terms of walking time to public transport stations and public transport service routes is significant (Acheampong and Asabere 2022).

Accessibility improvement and spatial inequality reduction play a positive role in transportation development and help achieve regional coordinated development. Public transit requires the construction of attractive and accessible public transit systems. Railway transport is one of the basic transportation systems in Europe (Čamaj et al. 2021). In strategic transport planning, rail stations play different roles at different scales (Zhang et al. 2021). The availability of railway stations and stops is one of the important aspects for the selection of rail passenger transport. Railway stations function as nodes in transport networks and places in an urban environment. Due to a possible unsatisfactory availability of railway stations and stops railway passenger carriers affected by this problem lose potential passengers, who prefer an alternative or more accessible mode of transport to rail transport (Bulíček and Bažant 2020). To serve the entire urban passenger transport system, urban rail transit, as the backbone of urban passenger transport, should closely cooperate with various modes of transport, such as the walking system and bicycles. Most accessibility measures use transit travel time as the sole determinant to decide whether an opportunity is accessible or inaccessible by public transport (i.e., isochronic models) or use the attractiveness of an opportunity (i.e., gravity models) (Salih and Lee 2022). Appropriate distance and time of passenger transfer from one point (residence, school, workplace, etc.) to another point (railway station or stop) and vice versa, are a crucial factor in passengers deciding which mode of transport to use. It is essential to know the situation of large passenger flows in railway hubs (Zhou et al. 2020). Innovation research and development as well as transport planning and coordination are a way to make rail transport a backbone of a sustainable public passenger transport system (Hlavatý and Ližbetin 2021).

2. Methods

Using the analysis of temporal and spatial availability of stations and stops, it is possible to determine which sources and destinations of the routes are within the specified walking distance, resp. attendance time. The analysis determines two isochrons for each station and stop, i.e. the connection of points with the same time availability from the specified point. Therefore, an accurate method for evaluating actual travel time is needed, especially for accurately delineating isochrones maps on a regional scale (Wang et al. 2016). On the contrary, the effects of both the location endowment metrics (accessibility and connectivity) in the railway network are significant. The determined isochrons represent distances of 500 m and 1,000 m.

Two values represent the time required to overcome each of these distances. The first value is determined using the Tobler function (De Abreu 2018). This function defines the dependence of the average walking speed of a healthy adult on the slope of the terrain. It is expressed by formula (1).

$$W = 6e^{-3,5\left|S+\frac{1}{20}\right|}, \qquad S = \frac{dh}{dx} = \tan\theta, \tag{1}$$

where W stands for average walking speed (km.h^{-1}), S for slope, dh for height difference, dx for distance and θ for

angle.

If the walk is realized on flat terrain, according to the Tobler function, the average speed of this walk is equal to 5.04 $km.h^{-1}$, or 1.40 $m.s^{-1}$. However, not all persons (handicapped, persons with luggage, children, etc.) move at the specified speed, therefore the time-consuming value for walking at a speed of 3.60 km.h-1, or 1.00 $m.s^{-1}$ determined for each isochrones = 1. The Tobler function multiplied by the constant 5/7 is used to functionally express the dependence of the walking speed of disadvantaged people on the slope of the terrain (Goodchild 2020). The calculated values of the time are rounded mathematically to whole minutes. The influence of the slope of the terrain can be neglected in some cases. These are mainly places with low terrain. Variability in both walking speed and distance is partially caused by journey time (Leurent and Xie 2017). In some cases, however, it is necessary to overcome a larger cant when walking, which reduces (or, conversely, increases) walking speed. In these cases, the rugged terrain can affect the time required for walking. For this reason, some isochrones have a deviation for walking in both directions. After determining the value of the cant between the isochron and the station or stop, the time required for walking at this detected cant in both directions is determined.

As part of the analysis of the region, it is first necessary to define which municipalities are part of it and also to analyse a demographic development and determine the area of the region. The integrated transport systems development brings new requirements for transport systems functions in the service of the selected area (Gasparik et al. 2020). An important task is to determine the territorial-administrative units that intervene in the defined region. It is essential to analyse the demand for and supply of railway transport and use statistical and cartographic techniques for that purpose (Jurkowski and Smolarski 2018). For the purposes of the analysis, the selected municipalities of the region are divided into following sets:

Table 1. The four sets of municipalities.

	Sets	Description
A	Municipalities through which the track passes	These are municipalities and cities whose cadastral territory the track passes directly through or municipalities whose urban area is relatively closely connected to these cadastral territories.
B	Municipalities around the line through which the line does not pass directly, with the expected potential	These are municipalities that are located near the investigated line, but for which it is not possible to satisfy the transport need by rail without the simultaneous use of alternative methods of relocation (public line transport, individual car transport, bicycle, walking outside the city, etc.) from the municipality to train and back.
C	Municipalities through which the adjoining railway lines pass	Municipalities that can be served by rail on connecting lines also represent a potential for the assessed line, especially with suitably set connections.
D	Municipalities with negligible potential	There are many municipalities in the region that, due to their geographical location or slope, represent a negligible potential for the implementation of routes using the services of the assessed line. These municipalities are not included in the analysis.

Objects were marked in the created areas of accessibility – educational institutions and medical facilities. Accessibility to the buildings was examined on foot from the train station or bus stop. The shortest distance from the nearest railway station or stop and the time required to walk this distance on foot were found for each of the buildings. This time is influenced by the altitude profile of the route as well as the walking speed. For a greater transparency, distances have been rounded to multiples of 5 and availability times to whole minutes up (Nachtigall and Ouředníček 2018). The distance was measured from the station building/shelter at the stop to the entrance to the selected institution or bus stop. For each of the individual time availability areas, the number of inhabitants who have access to rail transport was determined (Bulíček et al. 2021). The number of inhabitants in a certain area was calculated as the product of the number of housing units in each area of time availability and the average number of inhabitants in one housing unit, which is equal to:

$$ØP_{BJ} = \frac{P}{N_{BJ}}, \quad (2)$$

where $ØP_{BJ}$ stands for the average number of inhabitants in one housing unit, P for total population of the municipality (city), and N_{BJ} represents total number of housing units in the municipality (town).

The number of housing units in the time availability areas was performed by a manual census of houses and apartment buildings. The analysis of the potential of passengers in long-distance trains on selected routes is the basis for the design of a new concept of long-distance trains. It is a thorough analysis that clearly shows which routes long-distance trains should take and where they should stop.

Long-distance passenger transport is the main domain of rail transport. We see a lot of room for improvement here, which is the reason for tackling this issue. When analysing the potential of passengers, we are based on the current concept of long-distance trains, and the processing of this issue is consulted directly with experts from transport companies, which deal with the operation of long-distance trains in practice.

The aim is to calculate in detail the number of potential passengers on two selected routes. From the calculated values, then design a new concept of long-distance trains, which are to run on selected routes. The analysis must take into account the historical development, the current state, and all the specific features of the selected places. After processing the proposal, the selected sessions will be compared with each other. The determination of passenger potential is based on statistical indicators, which are defined with respect to the chosen methodology of the analysis process. Analysing the modal choice require lots of data related to transport, places, people, and employers referring to origins, destinations, and routes (Dobruszkes 2013). These data serve as a basis for determining individual indicators and the potential of passengers on selected routes. The potential of passengers on long-distance trains at a selected location on a selected route is the number of potential passengers who have access to that location, which allows them to use long-distance trains. Selected indicators must be used to determine passenger potential in detail:

- POO - Population of the municipality
- SPOOR - The sum of inhabitants in municipalities on the railway line
- SPOSO - The sum of the population of the surrounding area
- POOMSO - Population of the region outside the surrounding area
- POPOMSO - Population of the surrounding region
- SPC - Sum of potential passengers

3. Results

At the selected session, we will determine the places that are important in terms of determining the potential of passengers. These places must be chosen for objective reasons. All places where long-distance trains currently running on the selected route currently stop are automatically selected. To these are added all the district cities through which the route of the selected route runs, but long-distance trains do not currently stop there. In some cases, a given place is chosen for a specific reason, which is always stated in the relevant text for such a place. In each selected place, we must determine all the initial indicators described in the previous subchapter. In some cases, for methodological as well as logical reasons, some indicators or more indicators are omitted. Data from the indicators, which determine the total number of potential passengers in a given place, we write in a graphical editor, which creates a graph from them, from which we can clearly see the shares of individual indicators of potential passengers in a given place. In the relevant text, we will indicate the district in which the selected place is located. We will also list the previous and next place on the selected show, in which we determine the potential of passengers. Next, we will list the specific names of municipalities that were included in the individual indicators. These are municipalities that lie directly on the selected route and belong to the given place, as well as municipalities that are located in the catchment area of the given place. If necessary, we will also list the adjacent districts for the given place.

We will then list all the relevant information that needs to be provided for that location, i.e. specific conditions of the place. We will provide a brief comment on the results obtained, which will be aimed mainly at the reason why the place was chosen. The commentary presents the facts resulting from the results obtained and describes the impact of individual indicators on the total number of potential passengers in a given place. After evaluating all selected places on the selected session, we can make an overall evaluation of this session. Subsequently, it is possible to compare this session with another selected session and to propose an optimal solution for the operation, routing, and stopping of

long-distance trains on selected routes. The developed analysis of the potential of passengers on selected routes shows the number of potential passengers in selected places that are on these routes. The defined indicators form a complex structure of potential passengers in individual places, thanks to which we can take into account the specific conditions occurring in the given places. This analysis is the basis for the design of a new concept of long-distance trains, which are to run on selected routes (Fig. 1-4).

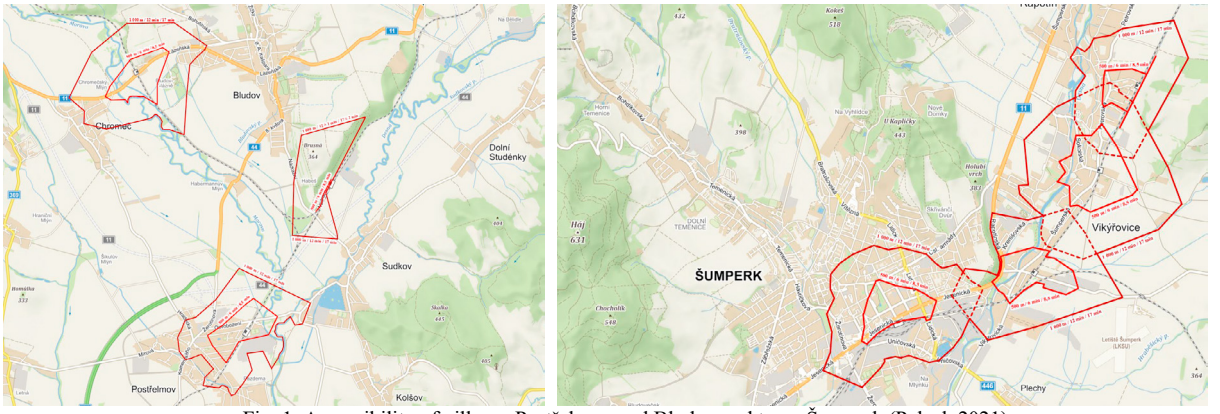

Fig. 1. Accessibility of villages Postřelmov and Bludov and town Šumperk (Palach 2021).

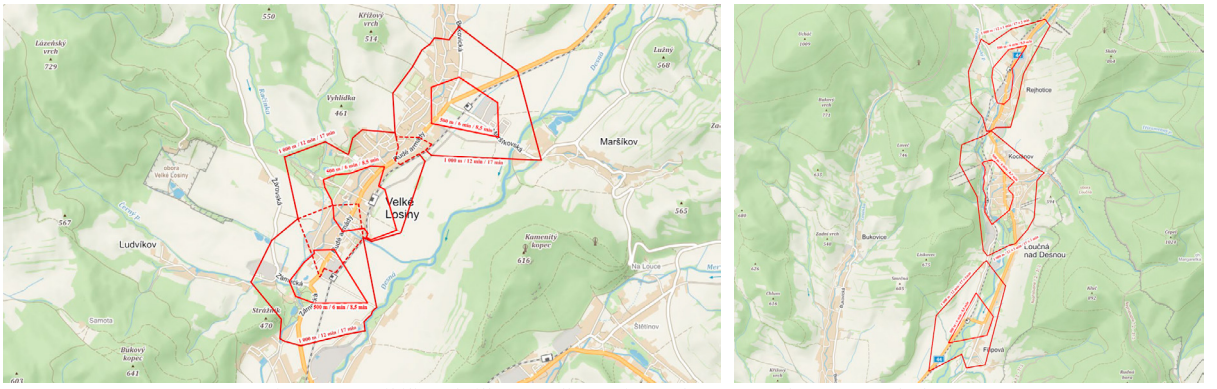

Fig. 2. Accessibility of villages Velké Losiny and Loučná nad Desnou (Palach 2021).

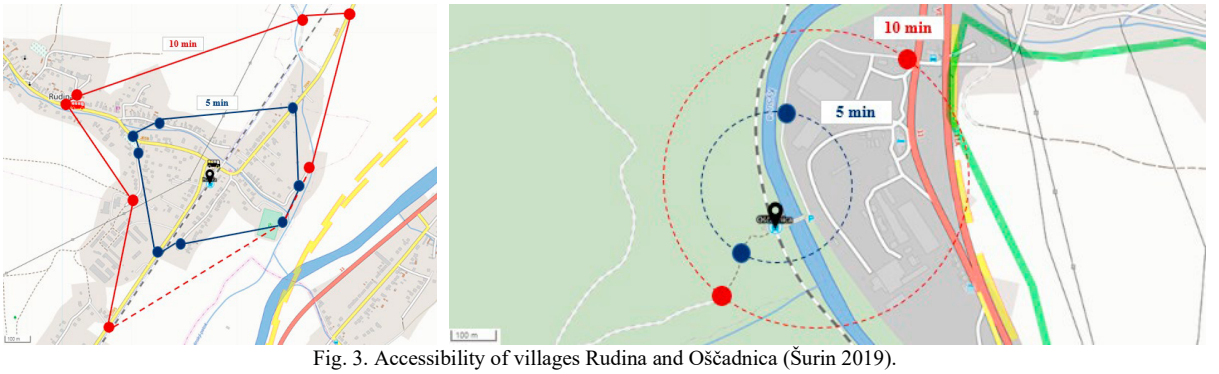

Fig. 3. Accessibility of villages Rudina and Oščadnica (Šurin 2019).

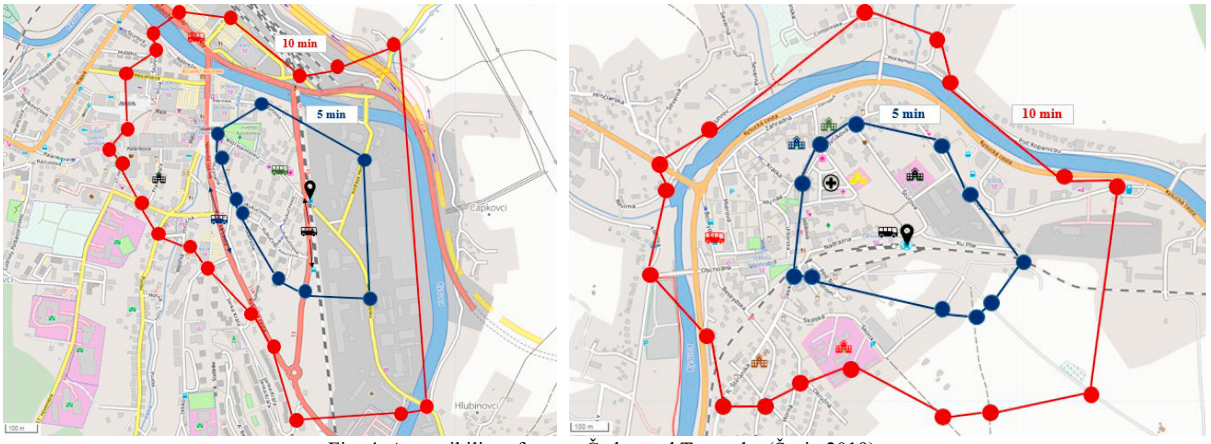

Fig. 4. Accessibility of towns Čadca and Turzovka (Šurin 2019).

The new concept of long-distance trains determines which routes long-distance trains should take, where they should stop and where it is important to ensure continuity between long-distance and regional trains. In a thorough analysis of the potential of passengers, we have reached specific numbers that give us the exact number of potential passengers in each place, which are located on selected routes. The sum of potential passengers at each designated place is made up of indicators that have been determined in the analysis methodology. However, when determining the total number of potential passengers on long-distance trains on the selected route, we cannot calculate the resulting numbers of potential passengers in the selected places, as some data could be included twice.

The potential of passengers of the selected route as a whole can be determined analytically by adding up the numbers of inhabitants of the districts through which the given session passes, to which we then add the number of inhabitants of all adjacent districts to the given session. These indicators will include all municipalities that lie on the selected route and also all municipalities located in the catchment area of the selected route. With such a procedure for determining the potential of passengers on the entire route, we will obtain the exact number of potential passengers, but we will not see their structure, which is, however, irrelevant in this case, as other specific conditions are not taken into account either (Fig. 5-7).

GALANTA (regional centre)

Indicators:	Legend:
POO:	15 063
SPOOR:	9 264
SPOSO:	91 769
POOMSO:	53 867
POPOMSO:	59 131
SPC:	**229 4**

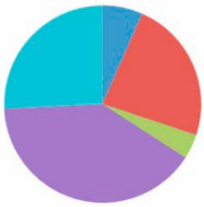

Fig. 5. Shares of potential passengers in Galanta.

JESENSKÉ (regional hub)

Indicators:	Legend:
POO:	2 240
SPOOR:	8 707
SPOSO:	25 663
POOMSO:	64 304
POPOMSO:	X
SPC:	**100 914**

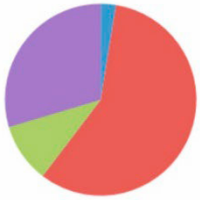

Fig. 6. Shares of potential passengers in Jesenské.

LEOPOLDOV (regional hub)

Indicators:	Legend:
POO:	4 130
SPOOR:	10 043
SPOSO:	113 652
POOMSO:	15 292
POPOMSO:	72 563
SPC:	**215 680**

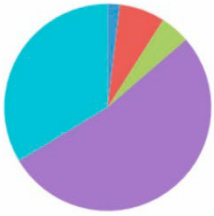

Fig. 7. Shares of potential passengers in Leopoldov.

4. Conclusions and Discussion

The paper focuses on several methods for measurement and evaluation of accessibility of railway stations and stops. First method as well as the second on are usable within regional passenger transport; while the third method evaluates the accessibility more widely and is more valuable for long-distance passenger transport. All these methods are applied to particular examples consecutively. Application provides proves that described methods have very good validity, but in every example some local specifications must have been taken into account. These specifications can limit the methods in some cases; therefore, it is necessary to evaluate the accessibility precisely always. Multicriteria analysis of these local specifications can be the subject of next research. Every aspect has different impact to the overall accessibility from temporal and spatial point of view.

First method is very usable in cases when it is necessary to evaluate the accessibility from space point of view. Isochrones represents the area, where people are not far from the railway station or stop, as the selected limit. Their values are 500 metres and 1,000 metres. This was dedicated by the consensus of transport experts from different fields.

The most important difference between the first and second method is the way of the evaluation. In the second method, the accessibility is evaluated from time point of view. It seems that nowadays it is more useful, because ordinary people are much more concerned to time than distance. Some physical barriers can also influence the difference between temporal and spatial accessibility. Application of these method also evaluates the travel destinations such as bus stops or schools, hospitals etc.

The third method is very useful in long-distance transport. In this kind of transportation, it is common that passengers transfer from regional trains or busses to long-distance trains in those stations, where these trains stop. It is the reason why the accessibility must be evaluated more widely (in the whole region). Information of the accessibility provides number of potential passengers, who can use the long-distance train. Due to this method, managers can decide which stations are better when they plan the train timetable.

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