Railway Passenger Transport Opportunities in the Banska Bystrica Region

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Abstract: Liberalized transport market, where the transport demand meets transport offer, is evolving dynamically. Due to market liberalization, transport companies tend to attach more importance to economic aspects. The paper is focused on statistical analysis of transport indicators in the Banska Bystrica region in comparison with the economic level of the region. The analysis is a background for the proposal of new long-haul passenger train route in the region. Technological part of the proposal consists of timetable, vehicles circulation and run of the train requisites while economic part consists of cost calculation and operating-economic evaluation. Operation of long-haul passenger trains on new route should improve transport accessibility in the region.

Keywords: railway transport, passenger transportation, transport economics, train operation

1. Theoretical background

In order to analyse the transport potential of the region while considering economic indicators we used a methods of time series and regression analysis. The time series of the variable $Y$ is a chronological sequence of the spatial, fact and time-comparable values $y_t$ for $t = 1, 2, ..., T$. \[1\]

So-called simple characteristics of time series are used to compare the development from past to presence. For our purposes we use:

- The growth coefficient (chain index) $k_t$ – it expresses how many times the value of $y_t$ has increased or decreased compared with its value in the previous period $y_{t-1}$. \[2\]

$$k_t = \frac{y_t}{y_{t-1}} \text{ for } t = 2,3, ..., T \quad (1)$$

- The base index $B_t$ – represents the relative change of the $y_t$ value in time compared with its value $y_0$ in the base period, which is considered as the basis of the comparison. \[2\]

$$B_t = \frac{y_t}{y_0} \text{ for } t = 1,2, ..., T \quad (2)$$

- The average growth coefficient (or average annual growth), calculated as the geometric mean of the selected growth coefficients $k_t$. \[2\]

$$\bar{k}_t = \sqrt[r]{k_1 \cdot k_2 \cdot ... \cdot k_T} \quad (3)$$

The regression analysis is a summary of statistical methods and processes used to study the relationships between two or more variables, the purpose of which is, in particular, to estimate

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the values or mean values of the dependent variable. [2] The simple linear regression model we use has the following equation:

\[ y_i = b_0 + b_1 x \] (4)

where \( y \) is a dependent variable, \( x \) is an independent variable, \( b_0 \) and \( b_1 \) are parameters of the regression model. The least squares method is used to estimate the model parameters. The minimum of the given function of the two variables \((b_0, b_1)\) is determined by the fact that its first partial derivations are set equal to zero. By adjusting we obtain a system of so-called normal equations. [3]

\[
\begin{align*}
\sum_{i=1}^{n} y_i &= nb_0 + b_1 \sum_{i=1}^{n} x \\
\sum_{i=1}^{n} y_i x &= a_0 \sum_{i=1}^{n} x + b_1 \sum_{i=1}^{n} x^2
\end{align*}
\] (5)

By solving this equation system we get the model parameter values. [3]

1.1. Economic Aspects of Railway Passenger Transport

Technology for operation of long-haul passenger trains is created by the transport company and passengers usually do not know it. They know only the timetable, what represents transport offer – number of connections on the route. Temporal position of trains, which are listed in the timetable, must be attractive for passengers. Timetable is created separately for both directions of trains. It must include all trains, their departures, stations and stops names, trains numbers and distances. Transport time between each station and stop must be determined by technical specifications of selected vehicle and infrastructure. Number of vehicles, which are necessary for operation of all trains included in timetable, is defined in vehicles circulation. It is divided into operation days and there is showed the sequence of trains for each vehicle and the following day. All technological acts are considered. Thanks to vehicle circulation, all vehicles have got same or very similar number of driven kilometres. Other part is a run of the train requisites. Train requisites are subjects, which are necessary to be supplemented into the vehicle, to create an object, which can independent movement in the transport process. Train requisites are vehicle-drivers and train crew. Sequence of the train requisites is regularly repeated schedule of their working time. Sequence of the train requisites must respect higher legal standards, mostly Labour Code. Thanks to sequence of the train requisites, the exact number of staff – vehicle drivers and cabin crew members, is known. From economic point of view, there must be operating costs calculation. Costs are financial representation of company sources consumption for realizing services per time. Internal costs of the transport company arise from operation of trains on railways. Thanks to calculation, the exact amount of these costs is known. In railway passenger transport, the calculation unit is the service – transporting of passengers. It can be defined by quantity (number of trains, vehicles), time (staff working time, time of traveling) or other way (passenger-kilometres, train-kilometres). In the case study, there are these costs: vehicle costs (price for vehicle, repairs and maintenance, insurance, operational cleaning), railway infrastructure access, staff costs (wages of vehicle-drivers and stewards), traction energy consumption and other indirect costs (management, marketing, travel ticket selling system, information system etc.). Sum of all costs, which are converted to one typified train on the route, is the base for making the tariff charges. [4]

Railway vehicle costs are calculated this way:
where:

\[ r_{\text{trkm}}^{RV} \] – railway vehicle costs rate for train-kilometre \( [\text{€/trkm}] \)
\[ D_Y \] – depreciation of vehicle per year \( [\text{€}] \)
\[ \Sigma R M_Y \] – entire costs for repairs and maintenance of vehicle per year \( [\text{€}] \)
\[ O C_Y \] – entire costs for operational cleaning of vehicle per year \( [\text{€}] \)
\[ I N S_Y \] – entire costs for vehicle insurance per year \( [\text{€}] \)
\[ \varnothing \text{ annual vehicle kilometrage} \] – average kilometrage of railway vehicle per year \( [\text{km}] \)

\[ C_{RV} = \Sigma T P_{\text{trkm}} \cdot r_{\text{trkm}}^{RV} \cdot N R V_{tr} \] (7)

where:

\( C_{RV} \) – entire railway vehicle costs per route \( [\text{€}] \)
\( \Sigma T P_{\text{trkm}} \) – transport performance (sum of train-kilometres per route)
\( r_{\text{trkm}}^{RV} \) – railway vehicle costs rate for train-kilometre \( [\text{€/trkm}] \)
\( N R V_{tr} \) – number of railway vehicles in the train on the route \( [\text{vehicles}] \)

Staff costs are calculated this way:

\[ r_{\text{empl}}^{S} = \frac{\text{price for working} + \text{equipment}}{\Sigma \text{work time}} \] (8)

where:

\( r_{\text{empl}}^{S} \) – staff costs rate for employee-hour \( [\text{€/empl}] \)
\( \text{price for working} \) – all month company’s costs for the employee \( [\text{€}] \)
\( \text{equipment} \) – month costs for equipment of employee \( [\text{€}] \)
\( \Sigma \text{work time} \) – entire month work time of employee \( [\text{hours}] \)

\[ C_{S} = t_r \cdot C R_{S} \cdot r_{\text{empl}}^{S} \] (9)

where:

\( C_{S} \) – staff costs per route \( [\text{€}] \)
\( t_r \) – train ride time \( [\text{hours}] \)
\( C R_{S} \) – conversion ratio: train ride time \( \rightarrow \) employee-hour
\( r_{\text{empl}}^{S} \) – staff costs rate for employee-hour \( [\text{€/empl}] \)

Traction energy consumption costs are calculated this way:

\[ C_{TEC} = \frac{\Sigma g t k m \cdot m c_{TE} \cdot r_{TE}}{1000} \] (10)

where:

\( C_{TEC} \) – entire traction energy consumption costs per route \( [\text{€}] \)
\( \Sigma g t k m \) – gross-tons-kilometres per route
\( m c_{TE} \) – measurable consumption of traction energy per thousand gross-tons-kilometres
\( r_{TE} \) – traction energy rate \( [\text{€}] \)
From operating costs calculation, tariff rates can be appointed. The tariff reflects valuable relations among operator and passengers. These rates must include internal goals of the transport company (increasing profit, decreasing costs, market share etc.), social sphere (quality and offer of public transport, reducing regional gaps etc.) and environmental aspects. Current transport demand and complementary transport offer are also important part of setting tariff rates. Fare is based on costs and appropriate profit and it is also dependent on transport demand and competition. Operating costs and transport revenues are compared in the operating-economic evaluation. Revenues are result of multiplying number of passengers with tariff rates, separately for each segment on the whole route. Comparison of costs and revenues express the economic efficiency of the route – revenues must be higher than costs. If the revenues are not higher than costs, operation of long-haul passenger trains is not efficient from economical point of view and the transport company must find external financial sources or simply remake the route. [5]

2. Characteristics of the economic level in the Banská Bystrica region

In assessing the transport potential of the region, we used the assessment of the development of time series of pre-selected socio-economic indicators that could influence the development of rail transport in the region over the period 2011-2016. The following indicators were chosen as decisive: regional gross domestic product at current prices, the average number of employed people as an indicator of employment in the region, average monthly wage, the number of cars as an indicator expressing the level of individual motoring, the level of industry in the region, expressed by the number of industrial enterprises and their cumulative revenues. On the basis of a comparison with other regions of Slovakia, we can assume that the Banská Bystrica region is characterized by the lowest employment rate as well as the lowest regional gross domestic product. It means that it is one of the economically weakest regions. As can be seen from Figure 1, regional GDP growth has consistently shown a positive trend with an average annual growth of 3%. For the period from 2011, the overall increase of this indicator was 17.3%. Compared with the economically strongest region, GDP was three times lower in 2016 and 29.8% lower than the average for all regions of Slovakia.

![Fig. 1 Progress of regional GDP in the Banská Bystrica region (source: authors)](image)

The employment level in the region firstly decreased sharply and subsequently started to show a positive trend. The positive side is that there is no long-term decline in employment in the region, although its rate in 2016 was lower by 22.48% compared to the average for all regions. The rate of individual motorism in the region is steadily rising. In 2016 the number of passenger
cars was almost 17% higher than in 2011, which is, of course, an unfavorable progress. However, unlike the previous indicators, in this case the development trend is comparable to other regions of Slovakia. The level of industry in the region is slightly below the average in terms of the number of industrial enterprises and their revenues. However, the development of enterprise values showed a predominantly positive trend. [6]

Table 1 shows the indices of changes in individual indicators in the Banska Bystrica region.

**Table 1** Indices of indicators change in the Banská Bystrica region (source: authors)

<table>
<thead>
<tr>
<th>Year</th>
<th>Regional GDP</th>
<th>Number of employees</th>
<th>Average monthly wage</th>
<th>Number of cars</th>
<th>Number of industrial enterprises</th>
<th>Returns of industrial enterprises</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012/2011</td>
<td>1.03</td>
<td>1.00</td>
<td>1.03</td>
<td>1.03</td>
<td>1.02</td>
<td>1.03</td>
</tr>
<tr>
<td>2013/2012</td>
<td>1.04</td>
<td>0.95</td>
<td>1.04</td>
<td>1.04</td>
<td>0.98</td>
<td>1.07</td>
</tr>
<tr>
<td>2014/2013</td>
<td>1.01</td>
<td>1.01</td>
<td>1.07</td>
<td>1.03</td>
<td>1.02</td>
<td>1.21</td>
</tr>
<tr>
<td>2015/2014</td>
<td>1.05</td>
<td>1.03</td>
<td>1.03</td>
<td>1.04</td>
<td>1.03</td>
<td>1.03</td>
</tr>
<tr>
<td>2016/2015</td>
<td>1.03</td>
<td>1.00</td>
<td>1.04</td>
<td>1.04</td>
<td>1.07</td>
<td>0.92</td>
</tr>
<tr>
<td>2016/2011</td>
<td>1.17</td>
<td>1.01</td>
<td>1.19</td>
<td>1.17</td>
<td>1.13</td>
<td>1.15</td>
</tr>
</tbody>
</table>

Table reflects their year-on-year growth rate as well as the average growth coefficient for the whole period. All socio-economic indicators showed positive growth over the period.

2.1. Analysis of the performance development on the line “Jesenské-Brezno” in terms of its dependence on the region's indicators

Based on passenger transport performance for 2011-2016 in train kilometres on the line “Jesenské-Brezno” (provided by the manager of the railway infrastructure manager ŽSR) we can assume that it keeps a predominantly rising trend over the given period. To elaborate performance analysis from region level, we chose economic indicator regional GDP. The linear dependency model was created using the MS Excel and Matlab software. Calculation of model parameters and their testing and the graphical representation is shown below.
R square model is 81.15%, and after testing by Fisher's statistical test, the statistical significance of this model was confirmed. We can therefore confirm the hypothesis that the development of performance on this line is linearly dependent on regional GDP. Even on the basis of the point forecast, it can be assumed that the region will create the right conditions for further growth of performance and the development of rail passenger transport in the future, whilst its potential is currently not fully exploited.

### 3. Case study

The case study is applied on the proposed circular route Zvolen – Lučenec – Rimavská Sobota – Brezno – Banská Bystrica – Zvolen, situated in the Banská Bystrica region. Operation of long-haul passenger trains on this route is ensured by unspecified vehicle with average technical parameters, similar to real vehicles, which operate on the railway infrastructure. Travel time respects all technical parameters of the vehicle as well as track. Nowadays, operation of long-haul passenger trains in the Banská Bystrica region consists of variety of different routes with various numbers and intervals of trains. These train routes cross borders of the region itself. In the figure 3, there are marked up contemporary routes of long-haul passenger trains in the Banská Bystrica region; in the second part of the figure, there are marked up numbers of long-haul train pairs according to each railway line part.
For improvement of the transport accessibility in the Banska Bystrica region, new long-distance passenger train routes should be established. New routes could be complement to contemporary routes on various transport connections however they should also offer new fast and direct connections for passengers.

Considering specificity of railway infrastructure in the Banska Bystrica region, there is an option for design of circular railway route. It means that train, which departed from Zvolen, went through Lucenec and arrived to Rimavská Sobota, could continue to Brezno, Banska Bystrica and back to Zvolen without a necessity of changing the ride direction. First part of route technology is the timetable proposal. To concise the paper, timetables are not shown separately, but all departures and arrivals of trains are shown in the train circulation. Time position of each train is set according to actual trains. Main function of new trains is to reduce the time gap between long-haul trains from current 4 hours to 2 hours on the section Zvolen – Rimavská Sobota. On the section Zvolen – Banska Bystrica, there are more trains mostly for commuting, because there live lot of people in these towns. Section Banska Bystrica – Brezno – Rimavská Sobota is a little bit different, because there is a great potential for tourism. All new long-haul trains are planned with big emphasis to actual trains so there are not any collisions and time position of actual long-haul trains have to be changed.

Next step is vehicles circulation. It shows the exact number of vehicles, which are necessary to realize the timetable. There are two vehicles, which are necessary for operation of all trains on the circular route from Zvolen to Rimavská Sobota.
Vehicle circulation is the base for determining driven kilometres of vehicles. It also influences operating costs calculation, because all vehicle costs are divided by average kilometres. Other important part is the run of the train requisites. Train requisites in passenger railway transport are vehicle-drivers and train crew – the necessary personnel of each train. There are one vehicle-driver and two members of train crew in each train. Their starting and termination point is Zvolen os. st. Economical part of the design consists of operating costs calculation. There are many enumerations, because all costs must be identified and quantified. Railway vehicle costs rate is quantified by formula (6).

**Tab. 2 Railway vehicle cost rate on the circular route Zvolen – Rimavská Sobota (source: authors)**

<table>
<thead>
<tr>
<th>RAILWAY VEHICLE COST RATE</th>
<th>Price (€)</th>
<th>5000000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Years of using</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Repairs and maintenance (€/year)</td>
<td>55000</td>
<td></td>
</tr>
<tr>
<td>Operational cleaning (€/year)</td>
<td>13000</td>
<td></td>
</tr>
<tr>
<td>Insurance (€/year)</td>
<td>26000</td>
<td></td>
</tr>
<tr>
<td>Annual vehicle kilometrage</td>
<td>247468</td>
<td></td>
</tr>
<tr>
<td>Resultant rate</td>
<td>1.05</td>
<td></td>
</tr>
</tbody>
</table>

Staff costs are calculated separately for vehicle-drivers and train crew. Firstly, the cost rate must be calculated. Key part is price for working – all costs of the transport company for one employee. All staff costs rate is quantified by formula (8). Train crew are less qualified than vehicle-drivers, therefore price for working is lower. Equipment costs are higher, because stewards are communicating with passengers, therefore they must have always clean and modern uniform for good propagation of the transport company. Basic precondition for the operating costs calculation is determination and summarization of all necessary inputs and other transport indicators, which are important parts for the calculation. When all inputs and transport indicators are known, the operating costs can be calculated. Costs per typified train are quantified by formulas (7), (9) and (10). Costs for infrastructure and indirect costs are quantified separately, according to methods hereinbefore. Revenues are calculated by multiplying of transport flows and tariff rates on each transport relations. Transport flows are determined by...
passenger counting in trains. Final and the most important part is the operating-economic evaluation, where revenues are compared with operating costs. Economic efficiency of the route is the result of this comparison and the operation of trains on the route is efficient in the case, when the result is higher than zero – revenues cover all costs. Operating-economic evaluation of the long-haul train route in the case study above shows the efficiency of the route. When revenues per train are higher than costs per train, the transport company can operate trains on the route according to submitted technology and external sources are not necessary. By comparing revenues and costs, it is possible to determine the economic efficiency of the train operation. Proposed circular route, which is showed in the case study, could be efficient from economic point of view, if the transport company can find some external sources for operation of trains, because revenues from transportation cannot cover all operating costs. On the other hand, this route would significantly improve transport accessibility of the Banska Bystrica region, especially bigger towns there. These trains could be also used for tourism.

4. Conclusion

If we want to improve transport accessibility in some region, we have to precisely analyse the region from economical point of view. From the analysis of the region, we can make some transport predictions. Firstly, potential passenger analysis shows the relevance of new train route. Secondly, technology part includes all necessary technical and technological aspects, such as timetable of trains, vehicle circulation and sequence of the train requisites. Operating costs calculation is very important part in the operating-economical evaluation, where all costs are compared with all revenues. This comparison is the key factor, because it shows economic efficiency of the new route. In the application of the methodology, new circular route Zvolen – Rimavská Sobota is not effective from economical point of view, because revenues are not higher than costs. The transport company should find other sources to cover all costs, than the operation of trains would begin.

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