EFFICIENCY OF RAIL FREIGHT TRANSPORT IN THE CENTRAL AND EASTERN EUROPEAN COUNTRIES

Rita Markovits-Somogyi, György Karmazin, Zoltán Bokor

Abstract: Assessing railway efficiency on the basis of up-to-date mathematical models delivers important benchmark information for decision makers. Moreover, it fosters and supports programmes aiming to improve railway infrastructure networks. Taking into account these facts, the present paper within the field of “economy of transport companies” investigates the efficiency of Central and Eastern European railways with special emphasis on freight transport. The position of the respective countries in different worldwide rankings, such as the Global Competitiveness Report and the Logistics Performance Index are also analysed. Finally, considering the indicative outcomes of the efficiency analysis the future development of the Hungarian railway network and its possible consequences are also highlighted.

Key words: railway efficiency, ranking, network extension

1. Introduction

Promotion of railway transport is one of the core elements in current transport policies. Railway networks are intended to be developed systematically so that the sustainability of the European transport system can be ensured. Within the corresponding policies special attention is paid to the Central and Eastern European countries as they constitute an important part of international corridors.

Before deciding on the development of railway networks, it is worth assessing the efficiency of the current railway systems and services. There are several methods available for this purpose and one of them is data envelopment analysis (DEA) [1]. Here an improved version of DEA is applied, called DEA pairwise comparison (DEA-PC), to evaluate the efficiency of rail freight transport in selected countries.

Having assessed railway efficiency the latest Hungarian rail network development plans are critically evaluated out with special regard to their expected effects on national and regional logistics performance.

2. The State of the Art of Railway Transport in Central and Eastern European Countries

Rail transport is known for being one of the most environment-friendly transportation modes, and indeed, its use is being encouraged by the European Union as well [2]. The following subsection gives a brief overview of the state of the Central and Eastern European railways, by highlighting and presenting the relevant cornerstone data. Figure 1. illustrates the rail speeds in the area investigated as based on the results from the ETISPLUS project. It can be seen, that Central and Eastern Europe is well covered with railway lines, although the speeds are visibly lower than in the areas more to the West. The network density can also be seen to become lower in this region.
Nevertheless, the performance and efficiency of railways does not only depend on the network but on the vehicle fleet as well. Figure 2 shows the number of locomotives registered in the different countries, distinguishing diesel and electrical engines. It has to be kept in mind, that the values depicted in the figures are absolute values not corrected for the size or the population of the respective country. It can be seen, that Poland, the Czech Republic and Romania dispose of the largest vehicle fleets.

A further important factor characterising the state of railways is freight transport performance, presented in Figure 3. With 43.445; 17.767 and 12.791 billion tonne-kilometres, respectively, Poland, Austria and the Czech Republic are the leading countries in this ranking.
Concerning quality, two different sets of indicators have been selected for introduction. The World Economic Forum ranks more than hundred countries worldwide each year to establish the Global Competitiveness Index (GCI). To create the index, 111 indicators are assessed which then serve as the basis for the calculation of GCI. One of these indicators is the quality of railway infrastructure. One of the data series in Figure 4, according to which the data have been ordered, presents the values of this indicator for year 2012. The other series is the “Logistics quality and competence” element from the Logistics Performance Index (2012), a survey by the World Bank, looking into the components and levels of logistics performance worldwide.
Even by merely looking at the data, a correlation can be discovered, which is then confirmed by carrying out a mathematical analysis showing a correlation of 98.88%. In this comparison, it is again Austria, the Czech Republic and Poland leading the group.

Finally, to include a further dimension into the analysis, the number of railway incidents is shown in Figure 5, which depicts the total annual number of victims excluding accidents involving level crossings and accidents to persons caused by rolling stock in motion; since in most of the cases these two categories cannot be construed as the responsibility of the railways.

![Figure 5: Calculated number of railway accidents (own edition as based on [4])](image)

As can be seen in the short introduction, several parameters can be used for evaluating the different aspects of railway transport. Nevertheless, integrated benchmark values such as relative efficiency and ranks based on these values can provide more sophisticated information. These relative values and ranks can be produced by the use of non-parametric calculations utilising various input and output indicators as presented in the following.

3. Railway Efficiency

a. Methodology

The efficiency of Central and Eastern European railways is investigated with two different approaches. First, traditional benchmark indicators are created and the countries are ranked using these indexes. Then, data envelopment analysis pairwise comparison method (DEA-PC) is applied using the same indicators; and in a further step, the examinations are extended to include additional aspects like sustainability.

The mathematical background of original DEA can be summarized in the following [7]: the basis is the solution of the next LP (linear programming) model, where we assume each DMU consumes $m$ different inputs, and produces $s$ different outputs, so for example $DMU_j$ consumes $x_{ij}$ of input $i$, and produces $y_{ij}$ of output $r$. $\varepsilon$ is a non-Archimedean element, defined to be smaller than any positive real number, $\phi$ is the index of efficiency to be maximised, $s$ are the slacks (related to the inputs and outputs), and $\lambda$ are weights. We also suppose that $x_{ij} \geq 0$, $y_{ij} \geq 0$, and for each DMU there is at least one positive input and one positive output [8].

$$\max \phi + \varepsilon \left( \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+ \right)$$  \hspace{1cm} (1)
subject to 
\[ \sum_{j=1}^{n} x_{ij} \lambda_j + s_i^- = x_{i0} \quad i = 1, 2, ..., m \]
\[ \sum_{j=1}^{n} y_{ij} \lambda_j - s_r^+ = \phi_{r0} \quad r = 1, 2, ..., s \]
\[ \lambda_j, s_i^-, s_r^+ \geq 0 \quad \forall i, j, r \]

Eq. (1) presents the output oriented CCR model (named after the researchers, Charnes, Cooper and Rhodes, having introduced it), the solution of which yields the results in constant returns to scale. With the addition of a further constraint
\[ \sum_{j=1}^{n} \lambda_j = 1 \quad (2) \]

converting the CCR model into the BCC (Banker, Charnes and Cooper) model, a VRS (variable returns to scale) approach is also possible [8].

Subsequently, the DEA-PC method can be described by the following way:
\[ \hat{\lambda}_{AB} = \max \sum_{r=1}^{s} u_r Y_{rA} \quad (3) \]
subject to 
\[ \sum_{i=1}^{m} v_i X_{iA} = 1 \]
\[ \sum_{r=1}^{s} u_r Y_{iB} - \sum_{i=1}^{m} v_i X_{iB} = 0 \]
\[ u_r \geq 0, \quad r = 1, ..., s, \quad v_i \geq 0, \quad i = 1, ..., m. \]

where
\[ \hat{\lambda}_{AB} \] the efficiency value resulting from the pairwise comparisons,
A, B index of the two, compared decision making units (DMUs),
\[ X_{ij} \geq 0, \quad Y_{ij} \geq 0 \] the input and output values of the decision making unit to be evaluated,
j = 1, 2, ..., n number of DMUs,
i = 1, 2, ..., m number of inputs,
r = 1, 2, ..., s number of outputs,
u_r, v_i \] the weights determined by the linear program.

The received \( \hat{\lambda}_{AB} \) efficiency values are ordered into a pairwise comparison matrix known from the analytic hierarchy process (AHP) method. Full ranking is then obtained by the coordinates of the eigenvector of the matrix [9].

b. Results

The productivity of infrastructure use, created as the simple ratio of freight transport performance and length of the network, can be seen as one of the series in Figure 7 (and the data have been ordered according to this ranking). The countries performing best from this aspect are Austria, Slovenia and Slovakia, the former two also being in the top three when ranking labour productivity calculated as the ratio of freight transport performance and number of employees, also shown in Figure 7 are analysed. As based on the data, Austria is
clearly an outlier in this context, which might be due to a more rationalised organisational structure of the respective railway companies.

When fleet productivity, the ratio of transport performance and fleet size are looked into (see Figure 8), Austria and Slovenia again perform very well.

Carrying out DEA-PC, different model structures have been investigated, which are summarized in Table 1. As the base case those inputs were selected, which have been individually examined as sheer productivity indicators. In line with scientific expectations, in this case DEA-PC yields results which can be construed as the synopsis of the outcomes from the previous analysis: Austria, Slovenia and Slovakia are leading this ranking (the ranking weights are shown in Figure 9 where the countries have been ordered according their ranking values originating from the base case).

Then, a further DEA-PC was carried out to take sustainability also into account (Case “Env.”). Here, an indicator characterising the composition of the vehicle fleet was introduced, in as much as the number of electrical locomotives was divided by the total number of locomotives. This can be regarded as a very broad indicator of environmental performance
and an input of DEA-PC.

Table 1: The different DEA cases

<table>
<thead>
<tr>
<th>Inputs</th>
<th>Base case</th>
<th>Env.</th>
<th>GDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Employment</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Fleet size</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Network size</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>GDP</td>
<td></td>
<td></td>
<td>x</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outputs</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Performance (tkm)</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Environmental perf.</td>
<td>x</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Finally, the GDP (in purchasing power standards) of the given country was also included into the investigations so as to take into account the difference of the economic environment. It has to be noted, that the examinations described could not have been carried out by traditional data envelopment analysis, outlined by Eq. 1., because there the thumb rule of application requires that the size sample should be three times as big as the sum of inputs plus outputs. However, by the introduction of DEA-PC this thumb rule could be circumvented, opening up the possibility of the analyses explained above.

The results from all the three cases are shown in Figure 9. It can be seen clearly how the ranking becomes altered as the perspective is changed to include further factors into the analysis. The third examination can be regarded as the most comprehensive one, extending to the influence of the economic environment and also considering sustainability.

Figure 9: DEA-PC results in the different cases (own research)

The results of the efficiency analysis show how successfully the national railway systems or the companies constituting them operate in the freight transport market. Of course the ranks vary according to the different input-output combinations. Nevertheless, this
additional information shall be utilised when determining the key elements of rail network development. This is the case in Hungary as well.

4. Details and Effects of the Planned Network Extension in Hungary

Looking at the rankings of Hungary in the different comparisons, it can be stated that this country does not deliver a particularly impressive performance in neither of the fields, nor in the final, comprehensive investigation. It is also well known from experts, that there is a serious lack of capacity at the Hungarian railways: it takes a train 18 hours to cross the country [10]. There are, however, plans to build a new railway line (V0) bypassing the capitol, thus alleviating railway traffic density on the networks in and around Budapest and increasing the above mentioned railway speed to 6 hours.

![Figure 10: Two alternatives of the planned V0 railway line [11]](image-url)

The first railway line in Hungary was inaugurated on 15th July 1846, and looking at the map of the Hungarian-Austrian Empire from the era, it is evident, that even at that time there were efforts to ease the burden of traffic in the middle of the country [12].

At the moment the feasibility study of V0 considers two different versions: one northern-southern and a southern line. It is planned to create an electrified, double-track line, fulfilling the highest expectations regarding quality, with a speed limit of 160 km/h, and an axle load of 225 kN on the whole length of the track. According to the present plans, V0 will connect Komárom and Szolnok, passing Székesfehérvár (or northern to that, in the region of Bicske and Erçsi), crossing the river Danube on a new bridge, and meeting the main railway line No. 100 by Cegléd. Depending on the alternative chosen, it requires the investment of 270 to 600 billion HUF and the length of the line will be 190 to 280 km. [11] The project is to be financed from national and European sources.

Provided that the necessary governmental level decisions are reached and both the financial resources and the necessary land is available, the construction can be started in 2017, and the line would be finished in 2023 at the soonest.

The expected positive effects of realising V0 are the following:

1. V0 will be able to alleviate the traffic on the Southern railway bridge which is connecting Kelefvöld and Ferencváros, and is a line passing close to the centre of Budapest;
2. it enables the increase of rail freight performance by at least 10% annually;
3. it might trigger economic activity in the region of Szolnok and Debrecen. These economic regions might become quicker to reach from the ports of the Adriatic and the Northern Sea. The reduction in travel times may be hours, or even days;
4. it creates the basis for logistic investments in the Záhony region as well;
5. it enhances the logistics competitiveness of Hungary and it contributes to positioning Hungary as an important transit corridor and logistics centre of Central and Eastern Europe;
6. it improves the situation of intermodal transport, thus making freight transport more sustainable and environment-friendly.

Hence, by means of V0, Hungary might play an important part regarding the European Transport Corridors, while this new infrastructure will also contribute to making the rail freight transport system more sustainable and the burden on the capital may also reduce considerably. With this bypass line such an infrastructure will be constructed, which renders „sustainable supply chains“ viable, and which facilitates the more intense cooperation of the relevant stakeholders.

Last but not least, the ranking position of Hungary concerning railway efficiency as well as the global indexes may significantly improve through the well established network development. This can be justified by the re-calculation of the DEA-PC model when the infrastructure development is realised.

5. Conclusions

The efficiency of railway systems or companies can be investigated effectively through the use of the DEA-PC methodology. Real benchmark values can be obtained and different ranks can be set up on the basis of the corresponding non-parametric decision support procedures. Analysing the results of the DEA-PC model applied for rail freight transport, it can be concluded that the national railway systems in Central and East European countries have different characteristics concerning efficiency. It shall, however, be noted that the results are sensitive to the selection of input and output parameters, which is to be taken into account when evaluating the model outcomes.

The countries of the examined region – including Hungary – shall pay special attention to the development of their rail infrastructure networks or systems. The principal aim of the proposed and applied methodology is to provide benchmarks and relative rankings for efficiency evaluations. At the same time it can contribute to the preparatory phases of rail development programmes by giving indicative information on the key interventions needed. Finally, after the realisation of the planned developments it is worth re-calculating the efficiency ranks so that the effects and impacts become more visible.

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