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REVIEW AND SYSTEMATIZATION OF EFFICIENCY MEASUREMENT METHODS USED IN THE TRANSPORT SECTOR

ABSTRACT

Efficiency analysis of transport systems can be carried out using numerous different techniques. Experts generally distinguish them as parametric and non-parametric methods, or else as methods using a production function, an index or not using anything of this kind. Based on the literature and on own research the present paper sets up a clear systematization of these techniques giving a brief summary of their essence while also providing examples of their application in the transport sector. Having elucidated each method, the author also outlines the correlation and the reliability of the techniques and presents a novel view which stresses the importance of links between the different techniques.

KEY WORDS

efficiency measurement, transport, TFP, MPI, SFA, DEA, OCRA

1. INTRODUCTION

The efficiency analysis of transport systems has got into the focus of scientific research in the last decades of the twentieth century. Efficiency has ever since been defined as a certain ratio of the outputs and the inputs of the given activity [1]. This approach, however, can be broken down in practice in many different ways and the international literature on the topic comprises several techniques for efficiency evaluation. Should one want to carry out their own efficiency analysis, it is useful to be able to orientate themselves in the maze of different techniques and approaches. The purpose of this paper is to systematize these methods and to provide an overview of the most important techniques. In order to do so, the author has studied several applications of various efficiency evaluation methods with special attention to their methodology, reliability and the correlation between them.

2. MAIN EFFICIENCY MEASUREMENT APPROACHES AND TECHNIQUES

From the review of the literature the systematization of the efficiency measurement techniques was carried out and a flow diagram (see *Figure 1*) has been created to outline the inner structure of the practical choices lying before us when selecting an efficiency measurement method. The flow diagram follows the traditional approach in that it distinguishes the techniques as the ones using an index, the ones using a production function (parametric approach) and the ones not using a production function (non-parametric approach). The rectangles indicate the decisions to be met, while the shaded forms present the techniques and versions selected. It has to be emphasized that the flow diagram indicates the methods most frequently employed for efficiency measurement in the transport sector. It is possible that there are further measures in the literature of other fields but those were not in the scope of the paper. The basic hypothesis is that, although all of the discussed methods can be utilised individually for the efficiency measurement of systems in the transport sector, methodologically they show overlapping elements. In the following the efficiency measurement techniques are to be presented as based on *Figure 1*, summarizing the main characteristics of each and giving examples of their utilization in the transport sector.

2.1 Use of indices

First it has to be decided whether an index and within that a “single” (non-decomposed) or a decomposed index is to be used. The choice of a *non-decomposed index* is justified when the data available are scarce and/or very general and solely of a financial nature. A multitude of such kind of indices exist; examples (also indicated in *Figure 1*) include Total Factor Productivity (TFP), the TFP Törnquist Index and the Complex Efficiency Index (CEI) [2].

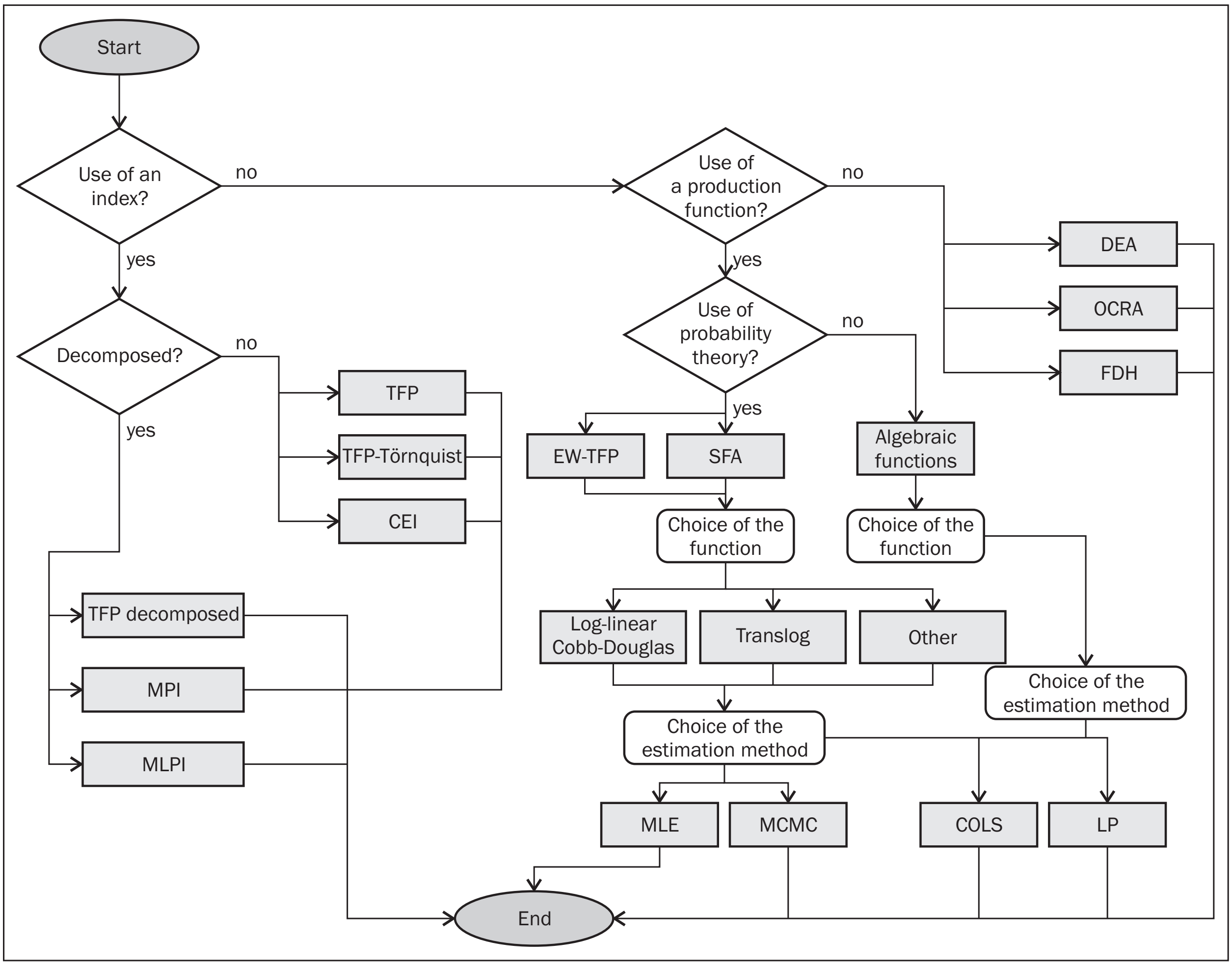

Figure 1 - The flow diagram outlining the choice between efficiency measurement techniques

$$TFP = \frac{Y}{K^{\alpha} L^{\beta}} \qquad (1)$$

where:

TFP – total factor productivity,
Y – added value (or output),
K – capital,
L – labour costs,
α, β – weights (in [2]: $\alpha = s$, $\beta = s - 1$, indicating a weighing which expresses what part of Y is due to labour (and the rest is assumed to be due to the capital).

$$Törnquist_{price\ index} = \prod_{m=1}^{M} \left[\frac{p_{mt}}{p_{ms}}\right]^{\frac{\omega_{ms}+\omega_{mt}}{2}}$$

$$m = 1, 2, \ldots, M \qquad (2)$$

where:

p_{mt}, p_{ms} – the price of the m-th good (or service) in period t and period s, respectively,
M – the number of goods or services,

$$\omega_{ms} = \frac{p_{ms} q_{ms}}{\sum_{m=1}^{M} p_{ms} q_{ms}}, \; \omega_{mt} = \frac{p_{mt} q_{mt}}{\sum_{m=1}^{M} p_{mt} q_{mt}}$$

q_{ms}, q_{mt} – the quality of the goods (or service) in period t and period s, respectively.

$$CEI = \frac{NPV}{0.1NE + 1.5LC} \qquad (3)$$

where:

CEI – complex efficiency index,
NPV – net value of production,
NE – net value of assets,
LC – labour costs.

These simple indices provide only a very broad judgement of the efficiency of the firms and that is why the decomposed indices have gained much place recently. Nevertheless it is important to be aware of their existence as they provide the basis for the decomposed indices and can give an estimation of efficiency if only few data are available.

The use of *decomposed indices* enables a much more sophisticated evaluation as it shows the effects of the different components. These can be, for instance, the decomposed TFP index, the Malmquist productivity index (MPI) and the Malmquist–Luenberger productivity index (MLPI). The decomposed TFP method relies on the TFP index given in Eq. 1, but it tries to pinpoint the reasons behind the efficiency values. Obeng and Sakano [3] for instance *decompose TFP* in such a way that input demand effect, pure scale effect, indirect output effect and pure technical change can all be investigated separately and the influence of subsidies can also be followed. A further example of TFP decomposition can be found in Graham [4] who employs it to analyse the efficiency of 89 urban railway companies. The authors of different papers are not decomposing TFP in a unanimous way; different researchers create their own approaches.

The *Malmquist productivity index* (MPI) and the *Malmquist-Luenberger productivity index* (MLPI) (sometimes also referred to solely as TFP indices) can also be decomposed to provide us with two (or more) aspects of efficiency. The basic form of the index is given by Eq. 4 [5].

$$MPI = \sqrt{\frac{\theta_{i,t+1}(y_{t+1},x_{t+1})}{\theta_{i,t+1}(y_t,x_t)} \cdot \frac{\theta_{i,t}(y_{t+1},x_{t+1})}{\theta_{i,t}(y_t,x_t)}} \tag{4}$$

where:

MPI – Malmquist productivity index,

θ_t – efficiency score for a given firm in period t,

$x_t = (x_{1,t},x_{2,t},\dots,x_{N,t})$ a vector of N non-negative inputs in period t,

$y_t = (y_{1,t},y_{2,t},\dots,y_{M,t})$ a vector of M non-negative outputs in period t.

i – indicates an input-oriented approach.

There are two major features of MPI – also visible from the equation – that have to be kept in mind. First, it is the time dynamics inherent in MPI: this index investigates the change in efficiency over time, thus it can be utilized in slightly different situations than the majority of the rest of the methods. Second, in order to achieve this dynamics, *a priori* information is necessary regarding the efficiency ranking of the firms in the different time periods. This information can be made available with other methods to be outlined later on, like the SFA or the DEA method. However, it is exactly this latter feature that enables the evaluation of efficiency change without the need to make behavioural assumption made during its construction. As Yu et al. [6] point out, it is also popular, because it rests upon the quantity of information, and no price information is necessary for its use.

Using the notations of Eq. 4, Eq. 5 presents the decomposed index [5]. The two basic components of the decomposed Malmquist index are efficiency change (also called the "catching up" index), and the technology change (also referred to as "frontier shift" index). Despite their names both indicate a sort of efficiency change: the former shows how the individual companies have improved in catching up with others on the frontier (i.e. the frontier created by the best performers), while the latter measures the change of frontier between the two time periods selected [7].

$$MPI = \frac{\theta_{i,t+1}(y_{t+1},x_{t+1})}{\theta_{i,t}(y_t,x_t)} \cdot \sqrt{\frac{\theta_{i,t}(y_t,x_t)}{\theta_{i,t+1}(y_t,x_t)} \cdot \frac{\theta_{i,t}(y_{t+1},x_{t+1})}{\theta_{i,t+1}(y_{t+1},x_{t+1})}} \tag{5}$$

where:

$$\frac{\theta_{i,t+1}(y_{t+1},x_{t+1})}{\theta_{i,t}(y_t,x_t)} = EFFCH \tag{6}$$

is the efficiency change component, and

$$\sqrt{\frac{\theta_{i,t}(y_t,x_t)}{\theta_{i,t+1}(y_t,x_t)} \cdot \frac{\theta_{i,t}(y_{t+1},x_{t+1})}{\theta_{i,t+1}(y_{t+1},x_{t+1})}} = TECH \tag{7}$$

is the technology change component.

Other authors up the index even further, like Barros and Weber [5], who examine within technology change the bias in the production of outputs, the bias in using inputs and the magnitude in the shift of the production frontier. A further interesting decomposition of MPI is presented by Yu et al. [6], who use MLPI to examine the effects of undesirable outputs. This allows for the possibility of crediting firms for the reduction in disagreeable effects. In this case the undesirable effect is aircraft noise; this factor is included in the efficiency evaluation of four Taiwanese airports over a five years time period using panel data. Further practical employment of the decomposed MPI index includes the efficiency measurement of 18 road toll companies in the period between 2002-2004 [7], of 25 regional airports of China between 1995-2004 [8], of 25 UK airports between 2000-2005 [5], and 26 Spanish airports between 1993-1999 [9].

2.2 Use of production functions

Another way of estimating efficiency is the application of production (or cost) functions; that is the econometric approach. The advantages and disadvantages of this approach lie at the same point: namely, the need for *a priori* assumptions about the relationship between the inputs used and outputs generated. It might prove difficult to construct the production function, but then the effects of different components can be easier measured than with non-parametric approaches and noise in the data can also be dealt with. Production functions can be deterministic (algebraic) and stochastic, the most frequently applied function forms being: the linear, the Cobb-Douglas, the quadratic, the normalised quadratic, the translog, the generalised Leontief, and the constant elasticity of substitution [10]. Due to the nature of the fields examined, the use of stochastic functions is much more present in the literature relating to transport and the technique employing this approach is generally called *stochastic frontier analysis* (SFA). SFA was created simultaneously by Aigner et al. [11] and Meeusen and van den Broeck [12], and is applied to measure the deviation of a firm's efficiency as compared to the best achievable target. In order to do this, first it creates the production function leaving room for random shocks and measurement error; and then evaluates the performance of the individual firms as compared to this frontier.

After Diana [13] the basic idea of SFA is as follows:

$$Y_i = f(x_i,\beta)\cdot TE \tag{8}$$

where:

Y_i – vector of M number of producer outputs,
$f(x_i,\beta)$ – the production frontier, and within that:
x_i – vector of N inputs used by the producer,
β – vector of (technology) parameters, and
TE – technical efficiency.

Eq. 8 can for example be rewritten in the following *log-linear Cobb-Douglas function* form:

$$\ln y_i = \beta_0 + \sum_n \beta_n \ln x_i + v_i - u_i, \tag{9}$$

and

$$TE_i = \exp\{-u_i\}, \text{ while } u_i \geq 0 \tag{10}$$

v_i – is the noise component with a two-sided normal distribution, and accounts for measurement errors, while
u_i – is the non-negative technical inefficiency with either a half normal, a truncated normal, an exponential, or gamma distribution,
$v_i - u_i$ – can also be viewed as the compound error term.

In the transport sector Eq. 8 can and is frequently estimated with the *translog function form* as well. Its general form is the following [10]:

$$y = \exp\left(\beta_0 + \sum_{n=1}^{N}\beta_n \ln x_n + \frac{1}{2}\sum_{n=1}^{N}\sum_{m=1}^{N}\beta_{nm}\ln x_n \ln x_m\right) \tag{11}$$

s.t. $\beta_{mn} = \beta_{nm}$ for all m and n, and where:

y – the dependent variable,
x_n – $(n = 1,2,\ldots,N)$: the explanatory variables,
β_n, β_{mn} – unknown parameters to be estimated.

Whichever production function is chosen, the parameters have to be estimated, which can be done with different methods. In case of a deterministic function, the corrected ordinary least squares method (COLS) or linear programming (LP) can be used. If the SFA method is selected, these two can still be applied (see [14]), or the maximum likelihood estimation (MLE) (see [15]) or the Markov Chain Monte Carlo simulation (MCMC) (see [16]) can also be employed.

Oum et al. [16] use SFA with a translog function to evaluate the efficiency of 109 worldwide airports, Diana [13] utilizes SFA with a log-linear Cobb-Douglas form for the examination of airport performance, Tsionas [17] combines SFA with a non-parametric method to investigate the efficiency of 10 US airlines over a 14 year long period, Cullinane et al. [15] look into the efficiency of 28 internationally very important container ports with an SFA method using a log-linear Cobb-Dougles production function, Coelli and Perelman [14] estimate the efficiency of 17 European railway companies with this method, employing a translog function and applying the LP and the COLS technique and Tovar and Martín-Cejas [9] use SFA as the basic method to calculate the efficiency rankings to be used in Malmquist productivity indexes in order to evaluate the efficiency of Spanish airports.

Finally, the *endogenous weight TFP* (EW-TFP) method has to be mentioned which is a unique technique in as much as it utilizes both an index and a production function, i.e. it creates an index from two functions: one that characterizes the input consumption, and the other which describes the production. Yoshida and Fujimoto [18] examine the efficiency of 67 airports with the method, and further examples of its employment can also be found in literature.

2.3 Use of non-parametric methods

Non-parametric methods differ significantly from the rest of the efficiency measurement techniques. The idea behind these is that they create a benchmark from the data of the sample available and compare all of the companies (or more generally, decision-making units, DMUs) to the best performing frontier. This is the biggest advantage to this method: there is no need to create previous assumptions about the characteristics of the production or service. Of course, this approach makes it more difficult to estimate the influence of different factors and outliers may influence the results (except in OCRA); but various techniques exist which help overcome these problems. Thus non-parametric methods are used extensively for the estimation of efficiency in the transport sector.

Beyond doubt, *data envelopment analysis* (DEA) is the most widely used non-parametric efficiency evaluation method. Its basic idea is presented below. Eq. 12 shows the weighted ratio of the outputs and inputs which is to be maximized for all the decision-making units. [19]

$$\max h_0(u,v) = \frac{\sum_{r=1}^{s} u_r y_{r0}}{\sum_{i=1}^{m} v_i x_{i0}} \tag{12}$$

where:

h – the function to be maximized,
m – the number of inputs consumed,
s – the number of outputs generated,
x_{ij} – the amount of input i consumed by DMU$_j$ where $i = 1,2,\ldots,m$,
y_{rj} – the amount of output r produced by DMU$_j$ where $r = 1,2,\ldots,s$,
j – number of DMUs,
0 – index of DMU being examined,

u, v – weights to be calculated, and subject to $x_{ij} \geq 0,\ y_{rj} \geq 0$and assuming that for each DMU there is at least one positive input and one positive output.

Applying the Charnes-Cooper transformation, the duality theory of linear programming and including non-zero slacks, Eq. 12 can be rewritten to yield the following envelopment model (input-oriented approach):

$$\min \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^{-} + \sum_{r=1}^{s} s_r^{+}\right) \tag{13}$$

s. t.

$$\sum_{j=1}^{n} x_{ij}\lambda_j + s_i^{-} = \theta x_{i0} \quad i = 1, 2, \dots, m$$

$$\sum_{j=1}^{n} y_{rj}\lambda_j - s_r^{+} = y_{r0} \quad r = 1, 2, \dots, s$$

$$\lambda_j, s_i^{-}, s_r^{+} \geq 0 \quad \forall i, j, r$$

where:

θ – efficiency value,

s_i, s_r – input and output slacks,

λ_j – weigths (developed as a result of the Charnes-Cooper transformation and the use of the duality theory),

ε – a non-Archimedean element, defined to be smaller than any positive real number.

The model described in Eq. 13 is the traditional DEA CCR method (named after the initials of its authors, Charnes, Cooper, Rhodes [20]), and can investigate the DMUs on a constant returns to scale basis. If the constraint of Eq. 14 is added to it, the result is the DEA BCC model (Banker, Charnes and Cooper [21]), which enables the examination of variable returns to scale situations.

$$\sum_{j=1}^{n} \lambda_j = 1 \tag{14}$$

Although DEA is not constructed in a way to facilitate the investigation of the effect of different components, if price information is available, above technical efficiency, allocative efficiency, overall efficiency, and even profit efficiency can be evaluated [19]. Moreover, various techniques have been developed to permit the analysis of the influence of different factors contributing to the efficiency ranking, e.g. the Tobit model, or its special case, the recently created Simar-Wilson procedure with a truncated bootstrap regression [22], [23],[24].

The literature on the application is immense indeed: airlines, railways, public transport companies, ports and airports are evaluated with the DEA method. Some of the most interesting examples include: Adler and Berechman [25] investigate airports from the airlines' view, carrying out a poll of the companies and then correlating this with a DEA VRS; Barros [26] examines 32 Argentinean airports with DEA and the Simar-Wilson methodology, Yu [27] performs a two-level DEA, focusing first on technical efficiency (i.e. the capacity provided by the transport company), then on service effectiveness (i.e. the number of seats sold) of railways. Tongzon [28] was the first to apply DEA to ports, and examined the efficiency of 16 international container ports, Sharma and Yu [29] did the same for 70 container ports using decision tree based, context dependent DEA model. Sampaio et al. [30] evaluated 19 public transport companies in Brazil and Europe, Hirschhausen and Cullmann [23] investigated the efficiency of 179 German bus transit companies.

Operational competitiveness rating (OCRA) is also a non-parametric efficiency measurement technique but it is applied considerably fewer times than DEA. The author of the present paper only found one example of its usage in the transport sector: Parkan [31] applied it to the evaluation of a public transit company. Nonetheless, as it has a very similar approach of the one used in the DEA method, OCRA is worth mentioning and discussing, even more so, since it claims to overcome some problems inherent in the DEA method. OCRA is a distance function based approach just as DEA. It measures the closeness of a DMU's (or in the OCRA terminology, the PU's – production unit's) performance from the ideal PU on a category by category basis, focusing on inefficiency in the following way [32]:

$$E_k = \sum_{m=1}^{M}\left[\frac{(C_{k,m} - \min_n\{C_{nm}\})a_m}{\min_n\{C_{nm}\}}\right] \text{ s.t. } \sum_{m=1}^{M} a_m = 1 \tag{15}$$

where:

E_k – resource consumption inefficiency rating of the k^{th} PU (in DEA terminology it would be called rather something like "input inefficiency"),

$C_{k,m}$ – cost of the m^{th} resource category for the k^{th} PU,

M – the number of cost categories,

C_{nm} – the n^{th} cost in cost category m,

a_m – calibration constant.

$$F_k = \sum_{h=1}^{H}\left[\frac{(\max_n\{R_{nh}\} - R_{k,h})b_h}{\min_n\{R_{nh}\}}\right] \text{ s.t. } \sum_{h=1}^{H} b_h = 1 \tag{16}$$

where:

F_k – value generation inefficiency rating of the k^{th} PU ("output inefficiency"),

$R_{k,h}$ – the revenue generated from the h^{th} category of outputs,

H – the number of revenue categories,

R_{nh} – the n^{th} revenue in revenue category h,

b_h – calibration constant, and

$$G_k = w_c E_k + w_r F_k \tag{17}$$

s.t. $wk_c + w_{kr} = 1$, for $k = 1, \dots, K$

where:

G_k – combined inefficiency rating of the k^{th} PU,

w_c, w_r – relative importance of a production unit's cost and revenue,

K – the number of production units.

It is worth noting that the method outlined in Eqs. 15-17 can only be followed if the measurement problem justifies the assumption of identical calibration constant distribution for all PUs, if that is not the case, a more complex method is to be applied. The developer of OCRA, Parkan, provides a method for the determination of the calibration constants, while he mentions that they could be settled with the use of other methods, like AHP as well. [32]

The merits of OCRA are claimed to be that the cost/revenue categories need not be the same for all PUs, so the comparison of dissimilar entities becomes possible, and the possibly small number of PUs or many cost and/or revenue categories, or even outliers in the data do not present a problem [33]. The main difference between OCRA and DEA is that in the former the weights are determined manually, while in the latter the LP itself quantifies them. This can be construed as an advantage to OCRA, in as much as the decision makers can make priorities with respect to different cost/revenue variations. However at the same time, these calibration constants seem to be the biggest stumble block of the method, they have even triggered a debate about the validity of OCRA.

Wang in a note [34] pointed out several problems with the method, the two most significant of them being that 1) OCRA measures efficiency on the basis of monetary value, but doing so the subjective judgement regarding the "importance" of the categories are superfluous (there are simpler solutions to do the same, e.g. ANOVA), 2) Concerning the calibration recommended by Parkan, he finds that the use of average cost/revenue shares as calibration constant values might ensure that \$1 less (or more) spent on a cost category would have the same effect on ratings as \$1 less (or more) spent in another category, i.e. the category with the higher cost is more important than the one with the lower cost. He says that this assumption is frequently incorrect, and so the ratings of OCRA do not reflect performance. He supported his arguments with an example of application. Parkan in his reply [35] showed that the results of Wang were based on an incorrect application of OCRA, and he also pointed out that in previous studies he had already applied OCRA to non-monetary inputs/outputs.

The author of the present paper finds that, indeed there were some mistakes in the calculation of Wang in as much as in his Scenario 1 he rounded certain calibration values which lead to the ranking criticized later on, but at the same time his theoretical viewpoint is correct. It is true that for an evaluation based on monetary values only, OCRA is not only too complex, but unnecessarily so. As for the calibration values: Parkan himself gets into contradiction when with his Scenario 1A and 1B proves contradictory statements: he creates the calibration values strictly on the basis of cost share and then claims that the cost category with larger cost/revenue ratio is not more important. The next section will analyse the correlation and reliability of the techniques outlined in Section 2, here OCRA is scrutinized again to see how it correlates with other efficiency evaluation techniques and it will be shown whether or not it is advisable to use this method.

Lastly, the *free/flexible disposal hull* (FDH) technique has to be cited, as a non-parametric method used for efficiency evaluation. It is mentioned by Coelli and Perelman [14] and Odeck [7]. The latter refers to two examples of its utilization, but both authors agree that it is a method rarely used. The reason might be its shortcomings: in FDH a DMU will be declared efficient by default if there are not sufficient number of observations on it and thus the method is discriminatory [7].

3. DISCUSSION ON THE CORRELATION AND LINKS BETWEEN THE METHODS

Having reviewed numerous efficiency evaluation methods, the question arises naturally whether all of these techniques yield the same results and in how much the individual methods can be expected to be robust enough. The authors of the various papers have conducted correlation analyses the results of which are revealing: Cullinane et al. [15] carried out a DEA and an SFA examination simultaneously and found a high degree of correlation between them. Coelli and Perelman [14] also investigated the parametric and the DEA method in parallel (the former also with LP and also with COLS estimation methods), and found that the three procedures yielded reliably similar results. Graham [4] compared results from the decomposed TFP method (created in such a way that it is comparable to the DEA method) and the DEA method, here also, the investigations yielded broadly the same rankings. Yoshida and Fujimoto [18] examined data processed with the EW-TFP and also with the DEA method, both techniques lead to the same results. Parkan [32] however found that the OCRA method gave similar results to DEA if and only if the DEA weighs were restricted to remain around the OCRA calibration constants. Jayanthi et al. [36] found no significant correlation between the efficiency values produced by the OCRA and DEA method. From this summary it can be concluded that the majority of the methods seem to lead to the same results. Only the OCRA method appears to be problematic. Bearing in mind also the difficulties in connection with the method it is perhaps reasonable not to utilize the technique in question, but the rest of the methods can be employed safely. Thus it can be stated that the methods enumerated in the paper – except for OCRA

– can all be individually applied for the efficiency measurement of transport systems.

Before the revision of the literature, the measures utilized for efficiency evaluation seemed to be distinct, and this feeling was reinforced by contemplating the traditional classification of the techniques (i.e. a) methods using an index, b) methods using a production function, c) non-parametric methods). The systematization of the techniques (in *Figure 1* and throughout Section 2) followed this classical idea. The author, however, believes that there are very strong inner links between the methods, which even overlap at times. *Figure 2* explains this discovered inner topography of the techniques. Naturally, the traditional indices have a very close relation to the decomposed TFP index (link 1), as they are its origin. MPI and MLPI have also much in common with the decomposed TFP index (2), as they use similar methods for the evaluation of different components in efficiency. At the same time MPI and MLPI cannot exist without the non-parametric methods (DEA, OCRA, FDH, hereinafter referred to as DEA) (3), or the SFA method (4), since they provide the input for the indices. The decomposed TFP and the DEA method are also very close (5), as the former can be construed in such a way that it becomes very similar to DEA. The decomposed TFP is also a “relative” of the econometric methods (like SFA) (6), as their handling of components contributing to efficiency is very much alike (a functional relation is present). While SFA and DEA are the two sides of the same coin (7): they estimate the same thing with and without the error term. Finally, EW-TFP method is the one which unites the most from the different methods seeing that its roots are in the simple indices (8), it is a relative of the decomposed TFP (9), it is based on the function forms similar to those of SFA (10), and creates an efficiency index as based on distance functions, just as DEA (11). Thus with *Figure 2* and the relations enumerated, the author would like to stress the finding that the efficiency analysis techniques in the transport sector are not distinctly standing methods, but rather they create a network of solutions from which the researchers have to select a procedure or a combination best suiting their needs. Consequently, and according to our basic hypothesis, it can indeed be stated that the techniques scrutinized show overlapping elements in their methodologies.

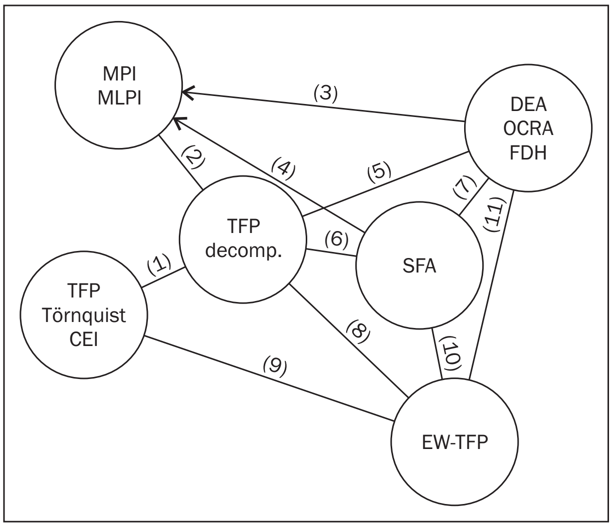

Figure 2 - Links between methods

4. CONCLUSION

The present paper has given a broad overview of the efficiency measurement techniques being used in our days for the evaluation of companies active in the transport sector. It can be seen that there are three major approaches for evaluation: the use of indices, the use of production functions and the use of non-parametric methods, the most prominent solutions being the decomposed TFP analysis, the SFA and the DEA method. Concerning correlation and reliability, it can be concluded that the review of the literature showed that all of the methods (except OCRA) provide a reliable estimation of efficiency as their results correlate to an appropriate extent. This is a fact to be appreciated as this means that the choice of an efficiency measurement technique can be independent of concerns for validity. It has also become clear that there are several interrelations between the methods, and so these cannot be handled as purely distinct solutions but rather as a web of efficiency measurement techniques. It shall be noted that other methodological approaches are also applicable when analysing or enhancing efficiency in transport and logistics. For example, improving the cost calculation procedures and the performance management regimes in transport can contribute to increasing the accuracy of resource allocations [37]. Furthermore, activity-based costing may be a powerful tool when allocating indirect costs to the examined products or services in logistics chains so that their profitability can be investigated more exactly [38]. Finally, with the advent of new techniques to be invented in the future, the review of efficiency measurement methods shall be a frequently recurrent topic for further research.

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ABSZTRAKT

A KÖZLEKEDÉSBEN HASZNÁLT HATÉKONYSÁGMÉRÉSI MÓDSZEREK ÁTTEKINTÉSE ÉS RENDSZEREZÉSE

A közlekedési rendszerek hatékonyságát számos különböző módszerrel lehet értékelni. A kutatók általában paraméteres és nem paraméteres módszereket különböztetnek meg, illetve úgy rendszerezik őket, mint a termelési függvényt alkalmazó, vagy mutatószámot használó illetve ezek közül egyiket sem alkalmazó eljárások. A cikkben a szerző a nemzetközi szakirodalom és a saját kutatásai alapján rendszerezi a különböző hatékonyságmérési eljárásokat, röviden összefoglalja a lényegüket és példákat hoz a közlekedési szektorban történő alkalmazásukra. Az egyes módszerek bemutatása után felvázolja az eljárások közötti korrelációkat, a módszerek megbízhatóságát és bemutat egy új szemléletmódot, amely a különböző technikák közötti kapcsolat fontosságát hangsúlyozza.

KULCSSZAVAK

hatékonyságmérés, közlekedés, TFP, MPI, SFA, DEA, OCRA

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