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ASSESSING THE EFFICIENCY OF LITHUANIAN TRANSPORT SECTOR BY APPLYING THE METHODS OF MULTIMOORA AND DATA ENVELOPMENT ANALYSIS

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Abstract. This study focuses on evaluating Lithuanian transport sector throughout 1995–2009 by applying multi–criteria decision making method MULTIMOORA (Multi–Objective Optimization plus the Full Multiplicative Form) and data envelopment analysis (DEA). MULTIMOORA provided ranks that enabled to perform time series analysis, whereas DEA made possible to identify both technical and scale inefficiencies. Due to limited data availability, we analyzed the transport sector as a whole, i. e. it was not decomposed into that of land, air, railway or water. Although every production factor, including labour, capital and land is required for developing the transport sector, due to limited data availability, it is not possible to tackle them all when performing analysis. Consequently, one input, namely energy consumption in transport, was considered in the conducted analysis. On the other hand, two forms of transport – passenger and freight transport – were distinguished, and each of them was measured using composite indicators of passenger and tonne kilometres respectively. These two indices were considered as the outputs of transport sector activity. The final ranks provided by MULTIMOORA indicate that the transport sector was operating most effectively during 2004–2008, whereas it exhibited relative inefficiency throughout 1996–1998. The application of DEA suggests that the efficiency downturn of 1996–1998 might have been caused by technical inefficiency, whereas that of 2008–2009 was driven by scale inefficiency. Indeed, the technical modernization of the transport sector as well as the resolution of resource allocation problems might have lead to an increase in technical efficiency. Meanwhile, economic downturn prevents the transport system from working at full capacity; hence, scale efficiency is still observed.

Keywords: multi-objective optimization, MCDM, MULTIMOORA, data enevelopment analysis, efficiency, transport sector, Lithuania, energy intensity.

1. Introduction

The assessment of the efficiency of a certain economic sector is of high importance when making strategic decisions at any management level. This study, hence, is aimed at evaluating Lithuanian transport sector by applying multi-criteria decision making (MCDM) method MULTIMOORA (Multi–Objective Optimization plus the Full Multiplicative Form) and data envelopment analysis (DEA). Due to limited data availability, we analyzed the transport sector as a whole, i. e. it was not decomposed into that of land, air, railway or water. Although every production factor, including labour, capital and land is required for developing the transport sector, due to limited data availability, it is not possible to tackle them all when performing analysis. Consequently, one input, namely energy consumption in transport, was considered in the conducted analysis. Indeed, relatively high energy intensity is peculiar for Lithuanian economy (Streimikienė *et al.* 2007; Klevas, Minkstimas 2004; Baležentis *et al.* 2010). Therefore, the identification of energy inefficient sectors is an important issue. On the other hand, two forms of transport – passenger and freight transport – may be distinguished, and each of them was measured using composite indicators of passenger kilometres (PKM) and tonne-kilometres (TKM) respectively (Ramanathan 2000). These two indices were considered as the outputs of transport sector activity. Moreover, two methods, namely MULTIMOORA and DEA, were employed in the performed analysis.

MCDM methods are becoming more and more actual nowadays. The widening spectrum of multi–criteria problems encompasses business decision–making, ranking schools, public procurements etc. (Peldschus, Zavadskas 2005; Peldschus *et al.* 2010; Kahraman 2008; Roy 2005; Ananda, Herath 2009; Zavadskas, Turskis

2011). There are many MCDM methods developed and aimed at the transparent decision process. In this study, the MULTIMOORA method will be applied when estimating the efficiency of Lithuanian transport sector. This method was introduced and developed by Brauers and Zavadskas (2006, 2010a). MULTIMOORA summarizes three methods thus offering robust ranking options. The method was applied for the manufacturing and engineering environment (Kracka *et al.* 2010; Chakraborty 2010; Brauers *et al.* 2008a, 2008b; Kalibatas, Turskis 2008) as well as for regional development studies (Brauers, Zavadskas 2010b; Brauers, Ginevičius 2009, 2010; Brauers *et al.* 2007, 2010; Baležentis *et al.* 2010). Hence, the MULTIMOORA method will be employed when evaluating the efficiency of the transport sector. However, MCDM methods provide ranking without any additional information. Therefore, the use of additional methods becomes an actual issue.

The DEA method, however, is peculiar with opposite characteristics. For DEA, it is a nonparametric method of measuring the relative efficiency of a decision making unit such as a firm or public–sector agency, which results in estimating actual as well as potential efficiency. Ranking based on such efficiency is usually not very robust (Jaržemskienė 2009). Nevertheless, DEA offers some additional information that soundly supports multi–criteria optimization. DEA was first introduced by Charnes *et al.* (1978). DEA is a relative, technical efficiency measurement tool that uses operations and research techniques to automatically calculate the weights assigned to the inputs and outputs of the production units being assessed (Kahraman 2008). Thus, no market prices are needed for calculations. Moreover, the need of the disaggregation of inputs and outputs is not the actual one. DEA was applied in the studies of agriculture (Alvarez, Arias 2004; Vinciūnienė, Rauluškevičienė 2009), transport (Hermans *et al.* 2008; Jaržemskienė 2009; Markovits-Somogyi 2011), healthcare (Rój 2010) and business performance (Halkos, Salamouris 2004; Chen, Ali 2004; Sufian 2010). Recently, many improvements to DEA have been offered (Shetty, Pakkala 2010; Zerafat Angiz *et al.* 2010; Wang *et al.* 2009). The DEA method will be applied in this study in order to evaluate the technical and scale efficiency of Lithuanian transport sector.

This research was carried out on the basis of data provided by Statistics Lithuania (accessible on-line (*http://www.stat.gov.lt*, see tables M7010301, M7010302, and M8020303) and covers the period of 1995–2009. This paper is organized as follows: Section 2 deals with MULTIMOORA, the following Section 3 describes DEA and finally, the empirical application of the latter methods is discussed in Section 4.

2. Ranking According to MULTIMOORA

This section contains an overview of the development of the MULTIMOORA method. The Multi-Objective Optimization by Ratio Analysis (MOORA) method was introduced by Brauers and Zavadskas (2006) on the basis of previous researches (Brauers 2003). This method was enhanced (Brauers, Zavadskas 2010a) and became a more robust method, namely MULTIMOORA (MOORA plus the full multiplicative form). These methods have been applied in numerous studies (Brauers *et al.* 2007; Brauers, Ginevičius 2009; Brauers, Zavadskas 2009, 2010b; Brauers, Ginevičius 2010; Baležentis *et al.* 2010; Brauers *et al.* 2010) focused on regional studies, international comparisons and investment management.

The MOORA method was proposed by Brauers and Zavadskas (2006). The method begins with matrix X where its elements x_{ij} denote the i-th alternative of the j-th objective ($i = 1, 2, \cdots, m$ and $j = 1, 2, \cdots, n$). In this case, we have $n = 3$ objectives – input and output indicators – and $m = 15$ alternatives – years 1995–2009. The MOORA method consists of two parts, namely the Ratio System and the Reference Point approach.

The Ratio System of MOORA. The system defines data normalization by comparing an alternative of an objective to all values of the objective:

$$x_{ij}^* = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \tag{1}$$

where: x_{ij}^* denotes the i-th alternative of the j-th objective (in this case, the j-th structural indicator of the i-th state). Usually these numbers belong to interval [0; 1]. These indicators are added (if a desirable value of an indicator is maxima) or subtracted (if a desirable value is minima) and a summary index of the state is derived in this way:

$$y_i^* = \sum_{j=1}^{g} x_{ij}^* - \sum_{j=g+1}^{n} x_{ij}^*, \tag{2}$$

where: $g = 1, \cdots, n$ denotes the number of objectives to be maximized. Then, every ratio is given the rank: the higher is the index, the higher is the rank.

The Reference Point of MOORA. The reference point approach is based on the ratio system. The Maximal Objective Reference Point (vector) is found according to the ratios found in formula (1). The j-th coordinate of the reference point can be described as $r_j = \max_i x_{ij}^*$ in case of maximization. Every coordinate of this vector represents the maxima or minima of a certain objective (indicator). Then, every element of the normalized response matrix is recalculated and the final rank is given according to deviation from the reference point and the Min–Max Metric of Tchebycheff:

$$\min_i \left(\max_j \left| r_j - x_{ij}^* \right| \right). \tag{3}$$

The Full Multiplicative Form and MULTIMOORA. Brauers and Zavadskas (2010a) proposed MOORA to be updated by the Full Multiplicative Form method embodying the maximization and minimization of a purely multiplicative utility function. The overall utility of the i-th alternative can be expressed as a dimensionless number:

$$U_i' = \frac{A_i}{B_i}, \quad (4)$$

where: $A_i = \prod_{j=1}^{g} x_{ij}$, $i = 1, 2, \cdots, m$ denotes the product of the objectives of the i-th alternative to be maximized with $g = 1, \cdots, n$ is the number of objectives (indicators) to be maximized and $B_i = \prod_{j=g+1}^{n} x_{ij}$ denotes the product of the objectives of the i-th alternative to be minimized with $n - g$ is the number of objectives (indicators) to be minimized. Thus, MULTIMOORA summarizes MOORA (i. e. the Ratio System and Reference point) and the Full Multiplicative Form. Ameliorated Nominal Group and Delphi techniques can also be used for reducing remaining subjectivity (Brauers, Zavadskas 2010a).

As one can note, the Reference Point prevents MULTIMOORA from becoming a fully compensatory technique. Whereas the Ratio System and the Full Multiplicative Form are fully compensatory methods, the Reference Point is the method based on the Min–Max metric of Tchebycheff and thus identifies certain alternatives peculiar with relative backwardness in either of criteria. Hence, MULTIMOORA is quite an effective tool for assessing the sustainability of various phenomena resulting in the unbiased ranking of alternatives.

3. Data Envelopment Analysis

Data Envelopment Analysis (DEA) is a nonparametric method of measuring the efficiency of a decision-making unit (DMU) such as a firm or public–sector agency (Ray 2004). The very term of efficiency was initially defined by Debreu (1951) and then by Koopmans (1951). Debreu discussed the question of resource utilization at the aggregate level, whereas Koopmans offered the following definition of an efficient DMU: *A DMU is fully efficient if and only if it is not possible to improve any input or output without worsening some other input or output*. Due to similarity to the definition of Pareto efficiency, the former is called Pareto–Koopmans Efficiency. Finally, Farrell (1957) summarized works by Debreu (1951) and Koopmans (1951) thus offering the frontier analysis of efficiency and describing two types of *economic efficiency*, namely *technical efficiency* and *allocative efficiency* (indeed, a different terminology was used at that time). The concept of technical efficiency is defined as the capacity and willingness to produce maximum possible output from a given bundle of inputs and technology, whereas allocative efficiency reflects the ability of a DMU to use inputs in optimal proportions considering respective marginal costs (Kalirajan, Shand 1999). However, Farrell (1957) did not succeed in handling Pareto–Koopmans Efficiency with a proper mathematical framework.

The modern version of DEA originated in studies by Charnes *et al.* (1978, 1981). Hence, these DEA models are called CCR models. Initially, the fractional form of DEA was offered. However, this model was transformed into input-output-oriented multiplier models, which could be solved by means of linear programming (LP). In addition, the dual CCR model (i.e. envelopment program) can be described for each of the primal programs (Cooper *et al.* 2006; Ramanathan 2003).

Unlike many traditional analysis tools, DEA does not require to gather information about the prices of materials or produced goods, thus making it suitable for evaluating the efficiency of both private and public sector. Suppose that there are $j = 1, 2, ..., t, ..., N$ DMUs, each producing $r = 1, 2, ..., m$ outputs from $i = 1, 2, ..., n$ inputs. Hence, DMU t exhibits input-oriented technical efficiency θ_t, whereas output-oriented technical efficiency is reciprocal number $\theta_t = 1/\phi_t$. Output-oriented technical efficiency φ_t may be obtained by solving the following multiplier DEA program:

$$\begin{aligned}
&\max_{\phi_t, \lambda_j} \phi_t \\
&\text{s. t.} \\
&\sum_{j=1}^{N} \lambda_j x_i^j \le x_i^t, \; i = 1, 2, ..., n; \\
&\sum_{j=1}^{N} \lambda_j y_r^j \le \phi_t y_r^t, \; r = 1, 2, ..., m; \\
&\lambda_j \ge 0, \; j = 1, 2, ..., N; \\
&\phi_t \text{ unrestricted.}
\end{aligned} \quad (5)$$

In Eq. (5), coefficients λ_j are the weights of peer DMUs. Noteworthy, this model presumes the existing constant returns to scale (CRS), which is a rather arbitrary condition. CRS indicates that the manufacturer is able to scale inputs and outputs linearly without increasing or decreasing efficiency (Ramanathan 2003).

Whereas the CRS constraint was considered over-restrictive, the BCC (Banker, Charnes and Cooper) model was introduced (Banker *et al.* 1984). The CRS presumption was overridden by introducing convexity constraint $\sum_{j=1}^{N} \lambda_j = 1$, which enabled to tackle variable returns to scale (VRS). The BBC model, hence, can be written as follows:

$$\begin{aligned}
&\max_{\phi_t, \lambda_j} \phi_t \\
&\text{s. t.} \\
&\sum_{j=1}^{N} \lambda_j x_i^j \le x_i^t, \; i = 1, 2, ..., n; \\
&\sum_{j=1}^{N} \lambda_j y_r^j \le \phi_t y_r^t, \; r = 1, 2, ..., m; \\
&\sum_{j=1}^{N} \lambda_j = 1; \\
&\lambda_j \ge 0, \; j = 1, 2, ..., N; \\
&\phi_t \text{ unrestricted.}
\end{aligned} \quad (6)$$

The best achievable input can therefore be calculated by multiplying actual input by the technical efficiency of a certain DMU. On the other hand, the best achievable output is obtained by dividing actual output by the same technical efficiency $\theta_t = 1/\phi_t$, where ϕ_t is obtained from Eq. (6). The difference between actual output and the potential one is called slack. In addition, it is possible to ascertain whether a DMU operates under increasing returns to scale (IRS), CRS or decreasing returns to scale (DRS). CCR measures gross technical efficiency (TE) and hence resembles both TE and scale efficiency (SE), whereas BCC represents pure TE. As a result, pure SE can be obtained by dividing CCR TE by BCC TE. Noteworthy, technical efficiency describes efficiency in converting inputs to outputs while scale efficiency recognizes that the economy of scale cannot be attained at all scales of production (Ramanathan 2003).

4. Results

The initial data are given in Table 1. One can notice that in this study each investigated year is treated as a separate DMU peculiar with a respective technological and economic environment. First, some general trends were observed during the period of 1995–2009. Energy consumption in the transport sector grew by 50% from 43502 terajoules (TJ) in 1995 up to 65228 TJ in 2009 with an average annual growth rate of 2.7%. The very peak of energy consumption was achieved in 2008 (79927 TJ). The volume of passenger transport shrunk by 16% from 5699 million PKM in 1995 down to 4790 million PKM in 2009 exhibiting an annual decrease rate in 1.2%. In addition, the volume of passenger transport reached its low and peak in 1999 and 2008 respectively. Meanwhile, the volume of freight transport grew by some 109% from 14409 million TKM up to 30061 million TKM in 2009 with an annual growth rate of 5%. Moreover, freight transport reached its peak in 2008. These initial findings suggest the existing correlation between economic crises of 1998–1999 and 2008–2009 and a weakened performance of the transport sector. However, we proceeded with multi-objective evaluation.

The application of MULTIMOORA began with normalization (Table 2) according to Eq. (1), see Table 2a. Subsequently, Eq. (2) was used in order to obtain the summarizing ratios of the Ratio System of MOORA

Table 1. Inputs and outputs of the transport sector, 1995–2009

Year	Volume of passenger transport, mill. passenger kilometres (PKM)	Volume of freight transport, mill. tonne-kilometres (TKM)	Energy consumption *E*, (TJ)
	MAX	MAX	MIN
1995	5699	14409	43502
1996	4933	14612	47331
1997	4444	16437	52535
1998	4205	16857	55011
1999	3831	18223	49157
2000	3873	20149	44212
2001	3894	20798	48455
2002	4074	25371	50016
2003	4017	28008	51081
2004	4975	28213	56121
2005	5310	32782	60356
2006	5444	33707	65697
2007	5680	35699	79387
2008	6381	35710	79927
2009	4790	30061	65228

Table 2. The Ratio System of MOORA and the Full Multiplicative Form (MF)

2a. The sum of squares and their square roots; the Full Multiplicative Form

Year	PKM	TKM	*E*	***MF***
1995	32478601	207619281	1892424004	1887.66
1996	24334489	213510544	2240223561	1522.91
1997	19749136	270174969	2759926225	1390.43
1998	17682025	284158449	3026210121	1288.54
1999	14676561	332077729	2416410649	1420.19
2000	15000129	405982201	1954700944	1765.07
2001	15163236	432556804	2347887025	1671.39
2002	16597476	643687641	2501600256	2066.57
2003	16136289	784448064	2609268561	2202.54
2004	24750625	795973369	3149566641	2501.02
2005	28196100	1074659524	3642846736	2884.09
2006	29637136	1136161849	4316095809	2793.14
2007	32262400	1274418601	6302295769	2554.20
2008	40717161	1275204100	6388325329	2850.92
2009	22944100	903663721	4254691984	2207.52
Σ	350325464	10034296846	49802473614	
Sq roots	18716.98	100171.34	223164.68	

2b. Normalized values of responses and the Ratio System (RS)

Year	PKM	TKM	*E*	***RS***
1995	0.304	0.144	0.195	0.253
1996	0.264	0.146	0.212	0.197
1997	0.237	0.164	0.235	0.166
1998	0.225	0.168	0.247	0.146
1999	0.205	0.182	0.220	0.166
2000	0.207	0.201	0.198	0.210
2001	0.208	0.208	0.217	0.199
2002	0.218	0.253	0.224	0.247
2003	0.215	0.280	0.229	0.265
2004	0.266	0.282	0.251	0.296
2005	0.284	0.327	0.270	0.341
2006	0.291	0.336	0.294	0.333
2007	0.303	0.356	0.356	0.304
2008	0.341	0.356	0.358	0.339
2009	0.256	0.300	0.292	0.264

(Table 2b). Eq. (3) was applied (Table 3) for the ratios obtained according to Eq. (1) therefore providing the ratios of the Reference Point of MOORA. Finally, the initial data were computed according to Formula (4) thus providing the ratios of the Full Multiplicative Form (Table 2a). The results of the Full Multiplicative Form and the Ratio System are shown in Figs 1 and 2 respectively. It is obvious that both methods suggest the transport sector operating the most effectively during the period of 2005–2008 in terms of the indicators considered. The Reference Point approach, hence, will be used as a control method for obtaining more robust results.

Table 3. The Reference Point of MOORA

3a. Coordinates of the reference point

	PKM	TKM	*E*
RP	0.341	0.356	0.195

3b. Deviations from the reference point

Year	PKM	TKM	*E*	max
1995	0.036	0.213	0.000	0.213
1996	0.077	0.211	0.017	0.211
1997	0.103	0.192	0.040	0.192
1998	0.116	0.188	0.052	0.188
1999	0.136	0.175	0.025	0.175
2000	0.134	0.155	0.003	0.155
2001	0.133	0.149	0.022	0.149
2002	0.123	0.103	0.029	0.123
2003	0.126	0.077	0.034	0.126
2004	0.075	0.075	0.057	0.075
2005	0.057	0.029	0.076	0.076
2006	0.050	0.020	0.099	0.099
2007	0.037	0.000	0.161	0.161
2008	0.000	0.000	0.163	0.163
2009	0.085	0.056	0.097	0.097

The Reference Point approach, therefore, provided additional information on measuring the relative efficiency of the transport sector. According to Eq. (3), the summarizing ratio for a certain time period is the maximum deviation (distance) from the reference values of each criterion. As Fig. 3 shows, these maximal values were defined according to different criteria during certain periods. For instance, the period of 1995–2001 was peculiar with relatively highest underperformance in the volume of freight transport (TKM), whereas that of 2002–2004 exhibited a reduced volume of passenger transport (PKM). Finally, according to the Reference Point, energy consumption was the most problematic indicator during 2005–2009.

The results of the three parts of MULTIMOORA are summarized in Table 4. The ranks were given by maximizing the ratios of the Ratio System and the Full Multiplicative Form and minimizing ratios (distances) from the Reference Point. The ranks provided by different parts of MULTIMOORA were summarized according to the dominance theory (Brauers, Zavadskas 2011). However, in this particular case, the final ranks coincided with those provided by the Full Multiplicative Form. To conclude, the final ranks provided by MULTIMOORA indicate that the transport sector was operating most effectively during 2004–2008, whereas it exhibited relative inefficiency throughout 1996–1998.

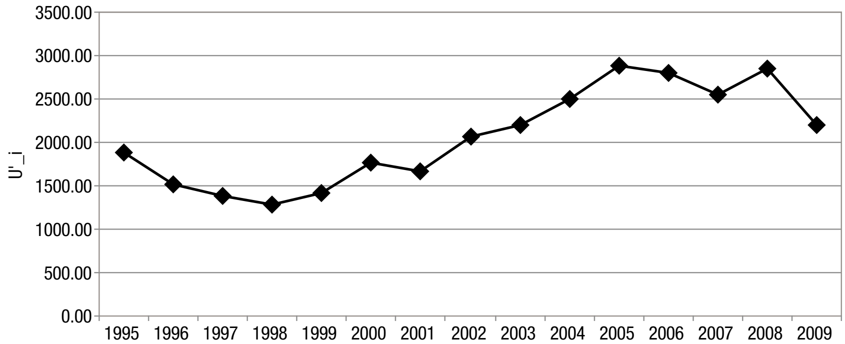

Fig. 1. The efficiency of Lithuanian transport sector according to the Full Multiplicative Form, 1995–2009

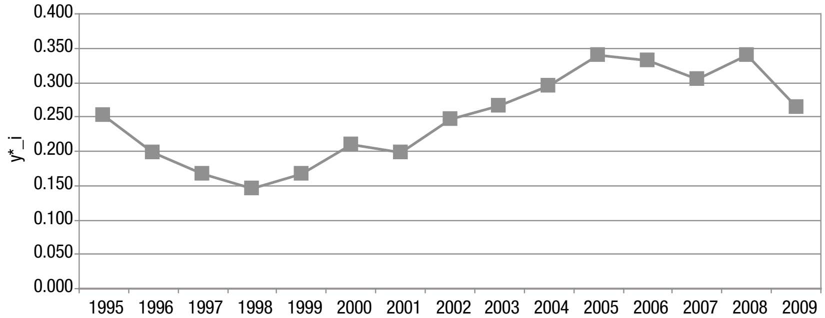

Fig. 2. The efficiency of Lithuanian transport sector according to the Ratio System, 1995–2009

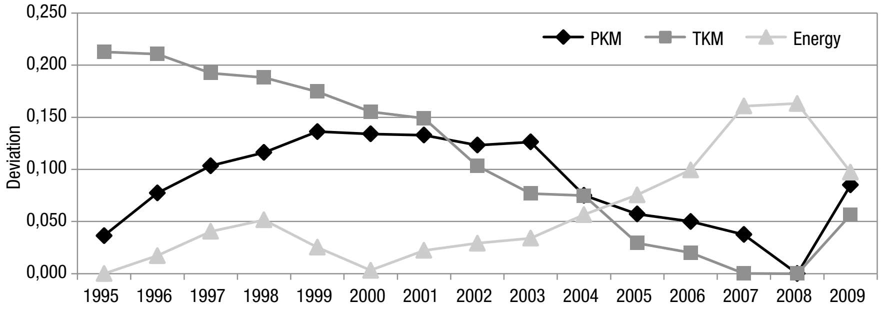

Fig. 3. Deviations of responses from reference values according to the Reference Point approach, 1995–2009

Table 4. The efficiency of the transport sector according to MULTIMOORA

Year	Ratio System		Reference Point		Full Multiplicative Form		Final ranks (MULTIMOORA)
	Ratios	Ranks	Ratios	Ranks	Ratios	Ranks	
2005	0.341	1	0.076	2	2884.09	1	**1**
2008	0.339	2	0.163	10	2850.92	2	**2**
2006	0.333	3	0.099	4	2793.14	3	**3**
2007	0.304	4	0.161	9	2554.20	4	**4**
2004	0.296	5	0.075	1	2501.02	5	**5**
2009	0.264	7	0.097	3	2207.52	6	**6**
2003	0.265	6	0.126	6	2202.54	7	**7**
2002	0.247	9	0.123	5	2066.57	8	**8**
1995	0.253	8	0.213	15	1887.66	9	**9**
2000	0.210	10	0.155	8	1765.07	10	**10**
2001	0.199	11	0.149	7	1671.39	11	**11**
1996	0.197	12	0.211	14	1522.91	12	**12**
1999	0.166	13	0.175	11	1420.19	13	**13**
1997	0.166	14	0.192	13	1390.43	14	**14**
1998	0.146	15	0.188	12	1288.54	15	**15**

DEA was performed by employing the *DEAP* package (Coelli 1996). The relative efficiency of the transport sector was estimated by employing Eq. (6). As Table 5 shows, the volume of both passenger and freight transport could have been increased by some 9.4% to reach the efficiency frontier given the observed energy consumption. More specifically, the largest slack was observed in 1998 (36.9%). Moreover, the application of Eq. (5) enabled to identify pure TE and SE (Fig. 4). It can be assumed, that the efficiency downturn of 1996–1998 might have been caused by technical inefficiency, whereas that of 2008–2009 was driven by scale inefficiency. Indeed, the technical modernization of the transport sector and the resolution of resource allocation problems might have lead to an increase in technical efficiency. Meanwhile, economic downturn prevents the transport system from working at full capacity, hence scale efficiency is still observed.

Hence, other economic sectors can be evaluated on the basis of the proposed analytical framework. In addition, the indicator system can be expanded by adding more indicators identifying certain inputs and outputs.

Table 5. Potential outputs of the transport sector according to DEA, 1995–2009

Years	PKM*	Slack, %	TKM*	Slack, %
1995	5699	0.0	14409	0.0
1996	5741.114	16.4	17005.71	16.4
1997	5740.618	29.2	21232.79	29.2
1998	5754.791	36.9	23069.8	36.9
1999	4855.771	26.7	23097.55	26.7
2000	3873	0.0	20149	0.0
2001	4441.207	14.1	23720.65	14.1
2002	4209.458	3.3	26214.57	3.3
2003	4017	0.0	28008	0.0
2004	5136.175	3.2	29127.02	3.2
2005	5310	0.0	32782	0.0
2006	5444	0.0	33707	0.0
2007	5680	0.0	35699	0.0
2008	6381	0.0	35710	0.0
2009	5432.233	13.4	33625.78	11.9
Mean		9.5		9.4

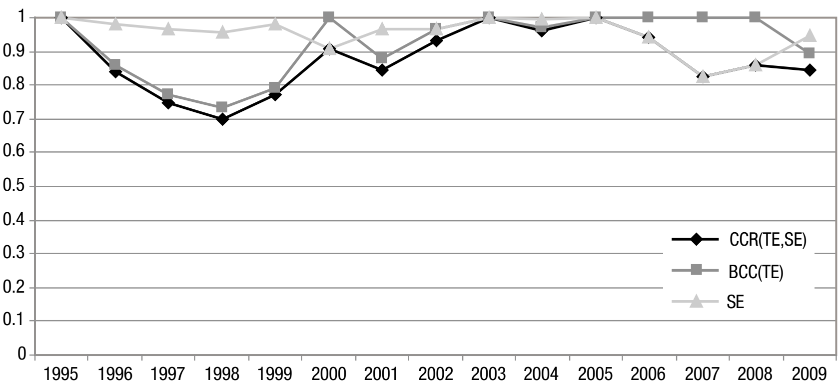

Fig. 4. Technical efficiency (TE) and scale efficiency (SE) of Lithuanian transport sector, 1995–2009

The findings of such studies might be important when making strategic decisions at various management levels. For instance, having observed the previous trends in operation efficiency, one can easily forecast the need of inputs.

5. Conclusions

The assessment of the efficiency of a certain economic sector is of high importance when making strategic decisions at any management level. Hence, the efficiency of Lithuanian transport sector was evaluated by applying multi–criteria decision making method MULTIMOORA (Multi-Objective Optimization plus the Full Multiplicative Form) and data envelopment analysis.

The final ranks provided by MULTIMOORA indicate that the transport sector was operating most effectively during 2004–2008, whereas it exhibited relative inefficiency throughout 1996–1998.

The application of DEA suggests that the efficiency downturn of 1996–1998 might have been caused by technical inefficiency, whereas that of 2008–2009 was driven by scale inefficiency. Indeed, the technical modernization of the transport sector and the resolution of resource allocation problems might have lead to an increase in technical efficiency. Meanwhile, economic downturn prevents the transport system from working at full capacity, hence scale efficiency is still observed. In addition, DEA with minimum weight restriction as well as other improvements might be applied for more robust results in further studies.

Hence, other economic sectors can be evaluated on the basis of the proposed analytical framework. In addition, the indicator system can be expanded by adding more indicators identifying certain inputs and outputs. The findings of such studies might be important when making strategic decisions at various management levels.

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