EVALUATION OF EFFICIENCY OF RAIL TRANSPORTATION OF BLACK SEA COUNTRIES BY USING AN INTEGRATED MCDM APPROACH

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Abstract

Black sea region is one of the most important regions of the world in the aspect of regional and global trade and its importance has ever-increased day by day. More importantly, applied new transport and logistics projects such as marine autobahn, short sea shipping, intermodal and combined transportations have continued to increase their importance. On the other hand, also competition among these countries increasing each passing days. They have tried to improve own abilities about logistics and transportation activities in order to increase own competitive power. Railway freight transportation is one of the most important competitive advantages in international and regional trade for these countries and it can provide many strategic advantages to these countries. On the other hand, countries should aware own abilities and positions about railway freight transportation activities and should measure own performance to make a more rational and realistic decision about logistics and transportation systems and infrastructure. Actually, because there are many variables and factors that affect the efficiency of rail freight transportation systems of countries, performance analysis for rail freight transportation is a multi-criteria decision-making problem and it can be solved with only MCDM techniques. Therefore, a hybrid MCDM approach, which consists of Entropy and EATWIOS techniques is suggested in order to provide a systematic and structural solution way in this study. Outputs and results of this study can contribute to filling the gap in the literature about rail freight transportation and efficiency analysis. more importantly, this model can be used easily by decision-makers, who play a role in logistics and transportation systems of countries to measure rail freight transportation performance and they can compare own performance with the railway freight transportation efficiencies of other countries.

Keywords: *Rail Freight Transport, Performance Analysis, EATWIOS, Entropy, logistics, MCDM*

1. INTRODUCTION

Railway transportation is one of the very important sectors for national, regional, and global economies. In addition to creating added values, it can provide connectivity among regions, countries, and companies. Especially, railway transportation plays a key role in the process of regional and global integration. Consequently, it can be seen that the connection and commercial relations between global and regional actors are not possible without healthy and well-operated railway systems. Not any transportation modes cannot give successful and efficient results more than railway transportation because it can provide lower transportation costs and can carry a heavy and high volume cargo to far distances. In addition to that, improved railway freight transportation systems can provide very important competition advantages, but countries and railway operators should aware own weakness and strong sides first. More importantly, it is required that they should use a systematic tool to measure their efficiency. This study proposes a systematic and structural way to evaluate the efficiency of rail freight transport systems of countries. This model consists of efficiency analysis technique with output satisficing (EATWOS) and entropy technique. While weight values of factors have been calculated by using the entropy method, performance scores of decision alternatives have been computed by the help of the EATWIOS technique. The black sea countries are selected as a case study and performance of their rail system have been analyzed by using integrated MCDM approach, which proposed in this study. This study consists of five sections and the importance and scope of this research have been summarized in the first section. In the second section, literature about railway freight transportation and efficiency analysis has been reviewed completely. While the multi-criteria decision-making model that suggested has been defined in the third section, a numerical analysis has been carried out in the fourth section.

Finally, outputs, which obtained as a result of this research have been evaluated and conclusions have been analyzed.

2. LITERATURE REVIEW

When the literature about railway performance analysis is reviewed, it is seen that any study does not exist related performance analysis of the rail freight systems by using OCRA method. Although they are in limited number, some studies also exist that using the various multi-criteria decision-making methods in order to use evaluation of the efficiency of railway transportation systems. Yu and Lin (2008) examined the efficiency and effectiveness in railway performance using a multi-activity network DEA model. Finger (2014) evaluated the relationship between performance and competition for European railways. Wetzel and Growitsch (2006) presented a study for evaluating the economies of scope in European railways in terms of efficiency analysis. Oum and Yu (1994) suggested using the DEA technique for analysis of economic efficiency of railways and Implications and by implementing for the OECD Countries' Railways, they tried to show that this method is working. WiegmanS and Donders (2007) evaluated benchmarking experiences of European railway companies in aspects of efficiency analysis. Bhanot and Singh (2012) examined the performance indicators of the Indian Railway container business using data envelopment analysis. Cantos, Pastor and Serrano (200) made an analysis for the Efficiency Measures and Output Specification for the European Railways. Lan and Lin (2014) proposed to use the DEA method to evaluate the technical efficiency and service effectiveness of railways industry. When studies realized for efficiency and performance analysis are reviewed, it can be seen that there are many studies using OCRA method in various fields. If they are summarized, some studies exist, which using the OCRA method such as Ozbek (2015a, 2015b, 2015c, 2015d, 2015e, 2016, 2017); Ozdemir (2018); Parkan, Peters et al. (2012); Soni and Banwet (2016); Wang (2017); Yang. (2011); Zufryden (1986).

3. MATERIALS AND METHODS

3.1. Materials

All numerical data have been obtained from statistics that published by official statistical institutions of selected countries as well as international institutions such as International Union of Railways (UIC), The Organisation for Economic Co-operation and Development (OECD), World Bank, The United Nations Conference on Trade and Development (UNCTAD), and The United Nations Economic Commission for Europe (UNECE). Numerical values of input and output factors, which determined completely consists of numerical data obtained from statics about railway freight transportation published by these institutions. As well as financial and non-financial sources, some factors such as infrastructure and superstructure elements used for railway transportation, human force are the main elements of input factors about rail freight transportation. Obtained total benefits, train movements, the total volume of transported loads, turnover and so on can be accepted as output factors. All input and output factor can be seen in Table 1 and 2.

Type	Codes	Definition	Unit
Accident	9104	Collision	Number
Accident	9105	Derailment	Number
Accident	9136	Total Accident	Number
Energy	8105	Diesel fuel consumption	Tonne
Energy	8108	Power consumption	Gigawatt/h
Financial Result	7213	Operating expenditure	million nat. currency

Financial Result	7408	State compensation and aid	million nat. currency
Financial Result	7610	Total investment	million nat. currency
Infrastructure	1110	Total length of electrified lines	kilometer
Infrastructure	1112	Total length of lines	kilometer
Infrastructure	1113	Length of tracks	kilometer
Infrastructure	1114	Length of electrified tracks	kilometer
Staff	3103	Mean annual staff strength - infrastructure	full time equivalent
Staff	3106	Mean annual staff strength - operations -	full time equivalent
Staff	3109	Mean annual staff strength - management	full time equivalent
Staff	3111	Mean annual staff strength - all sectors	full time equivalent
Stock	2104	Diesel Locomotives	number
Stock	2106	Electric Locomotives	number
Stock	2304	Total number of wagons	number
Stock	2306	Railway-owned wagons - Capacity	Tonne
Ext. Cost	9001	Share of CO2	%
Ext. Cost	9002	Total CO2 by Rail	Tonne

Table 1. Input Factors

Type	Codes	Definition	Unit
Financial Result	7223	Operating revenue	Million nat. Currency
Freight Traffic	6105	Revenue total number of ton	Thousand ton
Freight Traffic	6109	Revenue total tonne.km	Million ton-km
Freight Traffic	6603	Freight traffic total tonne.km	Million ton-km
Train Move.	1206	Freight train movements on the network	Thousand train-km
Train Move.	1209	Train-km on the network - Diesel traction -	Thousand train-km
Train Move.	1213	Train-km on the network - Electric traction -	Thousand train-km
Train Move.	1309	Gross hauled Ton-km Diesel traction	Million gross ton-km
Train Move.	1313	Gross hauled Ton-km Electric traction	Million gross ton-km
Train Move.	4106	Freight train movements of the operator	Thousand train-km
Train Move.	4206	Gross hauled tonne.km	Million gross ton-km

Table 2. Output Factors

3.2. Methods

In this study, a hybrid multi-criteria decision-making model that consists of entropy and efficiency analysis technique with output satisficing (EATWOS) is suggested. While the entropy method is used to calculate the weight values of input and output factors, the performance values of decision alternatives are computed by using implementation steps of EATWIOS method. This model consists of twenty implementation steps as seen in Figure 1.

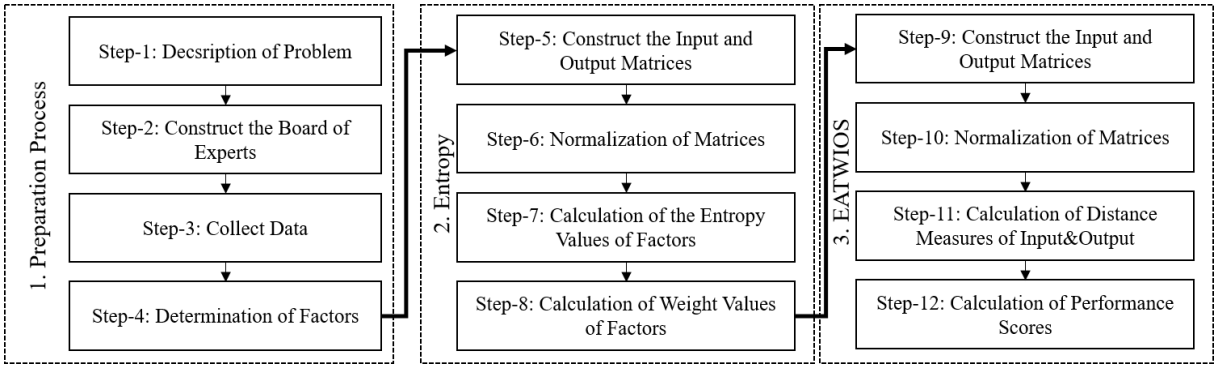


Fig. 1. Implementation Steps of the Model

In order to obtain more rational and realistic results and outputs, researchers have constructed board of experts consists of seven members who work in the field of railway transportation at least fifteen years as a senior executive or experts. Many round-table meetings were organized within this year together with these members in order to carry out this research and all input and output factors were determined by the board of experts. Moreover, collected all data and information were reviewed by the members to evaluate whether statistical data is healthily and accuracy and these data were used after given approvals by the board of experts.

3.2.1. Entropy Technique

Entropy method is probably the simplest and ergonomic technique to compute weight values of selection criteria and it can remove the necessity to use some MCDM techniques, which focus on the verbal judgments of decision-makers such as Analytic Hierarchy Process (AHP), Dematel, and so on. Actually, it consists of four implementation processes. In the first step, decision matrices are constructed and they are normalized in the second step. In the third step, entropy matrices are constructed and weight values of the factors are determined in the fourth and final step.

3.2.1.1. Construction of Input&Output Matrices

Input and output matrices are constructed in the first implementation step of the model. Matrix called x consists of values of factors, which are expected to take the minimum values. In order to obtain an optimal solution, these factors should take minimum values as far as possible. Matrix X can be constructed as seen in equation 1.

$$X = \begin{bmatrix} x_{11} & x_{12} & \dots & x_{1k} & \dots & x_{1K} \\ x_{21} & x_{22} & \dots & x_{2k} & \dots & x_{2K} \\ \vdots & \vdots & \ddots & \vdots & \dots & \vdots \\ x_{i1} & x_{i2} & \dots & x_{ik} & \dots & x_{iK} \\ \vdots & \vdots & \dots & \vdots & \ddots & \vdots \\ x_{l1} & x_{l2} & \dots & x_{lk} & \dots & x_{lK} \end{bmatrix} \quad (1)$$

$\forall i = 1,2 \dots, l;\ \forall k = 1,2 \dots, K$

Matrix Y shows the values of output factors as shown in Eq 2 and each element of the matrix represents obtained benefit. Actually, a decision-maker expects taking maximum value for each output factors.

$$Y = \begin{bmatrix} y_{11} & y_{12} & \dots & y_{1j} & \dots & y_{1J} \\ y_{21} & y_{22} & \dots & y_{2j} & \dots & y_{2J} \\ \vdots & \vdots & \ddots & \vdots & \dots & \vdots \\ y_{i1} & y_{i2} & \dots & y_{ij} & \dots & y_{iJ} \\ \vdots & \vdots & \dots & \vdots & \ddots & \vdots \\ y_{l1} & y_{l2} & \dots & y_{lj} & \dots & y_{lJ} \end{bmatrix} \quad (2)$$

$\forall i = 1,2 \dots, l;\ \forall j = 1,2 \dots, J$

3.2.1.2. Normalization of the Matrices

In the second implementation step of the model, all elements of the matrices are normalized with the help of Eq. 3 and Eq. 4 and normalized matrices are constructed as seen in Eq. 3a and 3b.

$$x^*_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (3a)$$

$$y^*_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}} \quad (3b)$$

In order to make normalization operation, each element of the matrices is divided into the sum of own column and the obtained value represents the element value of the normalized matrix. Normalized matrices X^* and Y^* can be constructed as seen eq. 4 and eq. 5.

$$X^* = \begin{bmatrix} x^*_{11} & x^*_{12} & \dots & x^*_{1k} & \dots & x^*_{1K} \\ x^*_{21} & x^*_{22} & \dots & x^*_{2k} & \dots & x^*_{2K} \\ \vdots & \vdots & \ddots & \vdots & \dots & \vdots \\ x^*_{i1} & x^*_{i2} & \dots & x^*_{ik} & \dots & x^*_{iK} \\ \vdots & \vdots & \dots & \vdots & \ddots & \vdots \\ x^*_{l1} & x^*_{l2} & \dots & x^*_{lk} & \dots & x^*_{lK} \end{bmatrix} \quad (4)$$

$\forall i = 1,2 \dots, l;\ \forall k = 1,2 \dots, K$

$$Y^* = \begin{bmatrix} y^*_{11} & y^*_{12} & \dots & y^*_{1j} & \dots & y^*_{1J} \\ y^*_{21} & y^*_{22} & \dots & y^*_{2j} & \dots & y^*_{2J} \\ \vdots & \vdots & \ddots & \vdots & \dots & \vdots \\ y^*_{i1} & y^*_{i2} & \dots & y^*_{ij} & \dots & y^*_{iJ} \\ \vdots & \vdots & \dots & \vdots & \ddots & \vdots \\ y^*_{l1} & y^*_{l2} & \dots & y^*_{lj} & \dots & y^*_{lJ} \end{bmatrix} \quad (5)$$

$\forall i = 1,2 \dots, l;\ \forall j = 1,2 \dots, J$

3.2.1.3. Construction of the Entropy Matrices

In the third step, by using Eq 6a and 6b, entropy values of all elements of each matrix are calculated and entropy matrices, which shows entropy values of input and output factors are constructed as shown in Eq. 7a and 7b.

$$e^*_{ij} = x^*_{ij} \,.\, lnx^*_{ij} \quad (6a)$$

$$e^-_{ij} = y^*_{ij} \,.\, lny^*_{ij} \quad (6b)$$

In order to compute the entropy value of each element, each element value of the normalized matrices is multiplied by own logarithmic value.

$$E^* = \begin{bmatrix} e^*_{11} & e^*_{12} & \dots & e^*_{1k} & \dots & e^*_{1K} \\ e^*_{21} & e^*_{22} & \dots & e^*_{2k} & \dots & e^*_{2K} \\ \vdots & \vdots & \ddots & \vdots & \dots & \vdots \\ e^*_{i1} & e^*_{i2} & \dots & e^*_{ik} & \dots & e^*_{iK} \\ \vdots & \vdots & \dots & \vdots & \ddots & \vdots \\ e^*_{l1} & e^*_{l2} & \dots & e^*_{lk} & \dots & e^*_{lK} \end{bmatrix} \quad (7a)$$

$\forall i = 1,2 \dots, l;\ \forall k = 1,2 \dots, K$

$$E^{-} = \begin{bmatrix} e^{-}_{11} & e^{-}_{12} & \dots & e^{-}_{1k} & \dots & e^{-}_{1K} \\ e^{-}_{21} & e^{-}_{22} & \dots & e^{-}_{2k} & \dots & e^{-}_{2K} \\ \vdots & \vdots & \ddots & \vdots & \dots & \vdots \\ e^{-}_{i1} & e^{-}_{i2} & \dots & e^{-}_{ik} & \dots & e^{-}_{iK} \\ \vdots & \vdots & \dots & \vdots & \ddots & \vdots \\ e^{-}_{l1} & e^{-}_{l2} & \dots & e^{-}_{lk} & \dots & e^{-}_{lK} \end{bmatrix} \quad (7b)$$

$\forall i = 1,2 \dots, l;\ \forall j = 1,2 \dots, J$

After the computation of the entropy value of each matrix element, the entropy value of each factor can be calculated by using Eq 8a and 8b.

$$E^{*}_{ij} = \left(\frac{-1}{ln(m)}\right) \sum_{i=1}^{m} \left[x^{*}_{ij} \,.\, lnx^{*}_{ij}\right];\ \forall j \quad (8a)$$

$$E^{-}_{ij} = \left(\frac{-1}{ln(m)}\right) \sum_{i=1}^{m} \left[y^{*}_{ij} \,.\, lny^{*}_{ij}\right];\ \forall j \quad (8b)$$

Uncertainty value (dj) for each factor is calculated by using Eq. 9a and Eq.9b.

$$d^{*}_{ij} = 1\text{-}E^{*}_{ij};\ \forall j \quad (9a)$$

$$d^{-}_{ij} = 1\text{-}E^{-}_{ij};\ \forall j \quad (9b)$$

3.2.1.4. Calculation of the Weight Values of the Input&Output Factors

By using Eq. 10a and 10b, weight values of all input and output factors can be calculated.

$$w^{*}_{ij} = \frac{d^{*}_{ij}}{\sum_{i=1}^{m} d^{*}_{ij}};\ \forall j \quad (10a)$$

$$w^{-}_{ij} = \frac{d^{-}_{ij}}{\sum_{i=1}^{m} d^{-}_{ij}};\ \forall j \quad (10b)$$

3.2.2. Efficiency Analysis Technique with Output Satisficing (EATWOS)

EATWIOS is a very effective tool to measure the efficiency of decision options. More importantly, it can provide an opportunity to make a comparison among all decision alternatives in the aspect of their performance. It was developed by Peter and Zelewski. Because this method is developed in a short time ago, there are a limited number of studies that basis this technique. In order to reach an optimal solution, this method, which as seen below, follows four implementation steps.

3.2.2.1. Construction of Decision Matrices

In the ninth step of the model, input and output matrices that constructed in the first step of the model uses as is.

3.2.2.2. Normalization of the Decision Matrices

Elements of decision matrices are normalized by using Eq. 11a and 11b. While Eq. 11a is used for input factors, Eq 11b is used for output factors. After these normalization operations, two normalized matrices are constructed for both input factors and output factors. While Matrix R represents input factors (Eq. 12a), Matrix S is constructed for output factors (Eq. 12b).

$$s_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}};\ \forall j \quad (11b)$$

$$r_{ij} = \frac{y_{ij}}{\sum_{i=1}^{m} y_{ij}};\ \forall j \qquad (11a)$$

$$R = \begin{bmatrix} r_{11} & r_{11} & \dots & r_{1j} \\ r_{21} & r_{22} & \dots & r_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ r_{l1} & r_{l2} & \dots & r_{lj} \end{bmatrix} \qquad (12a)$$

$$S = \begin{bmatrix} s_{11} & s_{11} & \dots & s_{1j} \\ s_{21} & s_{22} & \dots & s_{2j} \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ s_{l1} & s_{l2} & \dots & s_{lj} \end{bmatrix} \qquad (12b)$$

3.2.2.3. Calculation of Distance Measures of Input&Output Factors

In order to determine the distance measure of input factors, the minimum value of each column of the input matrix is determined. Afterward, the distance measure of each input factors is calculated with the help of eq 13b.

$$s^*_k = min\{\vec{r_j}\};\ \forall j = 1,\dots,J \qquad (13a)$$

$$ip_{ik} = 1 + (s_{ik} - s^*_k);\ \forall i = 1,\dots,k \qquad \forall k = 1,\dots,K \qquad (13b)$$

For output factors, the maximum value for each column of the output matrix is determined by using Eq 13c and with the help of Eq 13d distance measures of each factor is calculated for output factors.

$$r_{ij} = max\{\vec{s_k}\};\ \forall k = 1,\dots,K \qquad (13c)$$

$$op_k = 1 - \left(r^*_j - r_{ij}\right);\ \forall i = 1,\dots,l \qquad \forall j = 1,\dots,J \qquad (13d)$$

Finally, distance measure values are multiplied by weight values of factors that calculated in the first four steps and distance measure values are weighted. In this step, eq 14a and eq 14b are used as shown below.

$$ip_{ja} = ip_{ik}.w^*_{ij} \qquad (14a)$$

$$op_{ka} = op_k.w^-_{ij} \qquad (14b)$$

3.2.2.4. Calculation of Performance Scores

For each decision option, the sum values of the weighted distance measure of both input and output factors are computed separately. The obtained input value for each decision option is divided into the sum of the output values of the same option by using eq 15 and performance score is calculated for each decision alternative.

$$F_i = \frac{\sum_{j=1}^{J} ip_{ja}}{\sum_{k=1}^{K} op_{ka}} \qquad (15)$$

4. NUMERICAL ANALYSIS

The efficiency of railway freight transportation of eight Black sea countries was evaluated and analyzed in this study. These countries were decision alternatives and their performances were examined by using an integrated MCDM approach in the light of selected input and output factors. In order to make an effective performance analysis data collected from official statistics, which published by international institutions and countries, were used only. Except for steps in the preparation process, implementation steps of the proposed model show as below.

4.1.1.1. Construction of the Input and Output Matrices

The matrix X for input factors and the matrix Y for output factors were constructed after data about input and output factors were collected.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
Bulgaria	3	15	38	4	219	391	69	8.177	2.868	4.029	6.475	4.726	11.490	1.596	9.636
Georgia	4	1	19	2	4	44	33	753	1.415	1.415	1.644	1.644	6.705	1.213	457
Greece	1	3	13	47	41	714	53	217	520	2.240	2.764	933	4.936	2.089	672
Russia	3	4	12	2	130	13.997	879	2.118	43.621	85.375	85.375	43.621	327.590	70.040	744.275
Ukraine	2	5	10	5	139	190	47	1.213	10.277	21.603	46.997	27.835	7.889	26.011	56.890
Romania	3	5	179	16	137	295	161	1.480	4.030	10.766	23.568	8.473	483	1.969	11.165
Serbia	6	16	119	2	120	60	123	440	1.279	3.736	5.082	2.263	9.505	1.115	6.347
Turkey	6	23	120	20	217	106	70	928	3.856	10.131	12.532	4.350	13.953	3.372	9.377

Table 3. Matrix X

	I16	I17	I18	I19	I20	I21	I22
Bulgaria	21.308	174	235	269.538	269.538	0,40	993.934
Georgia	11.871	81	124	12.448	777.724	0,49	3.946.779
Greece	672	143	30	3.158	129.081	0,80	4.340.992
Russia	807.384	8.402	9.098	60.295	3.765.077	1,26	20.425.497
Ukraine	248.947	2.195	1.720	173.370	7.714.275	1,40	728.577
Romania	16.168	1.128	784	35.553	1.583.395	2,22	33.647.094
Serbia	15.853	170	133	7.277	411.158	0,51	2.969.601
Turkey	24.127	543	125	19.570	891.326	0,82	51.482.084

Table 3. Matrix X Continue

At the same time, matrix Y for output factors has been constructed as seen below.

	Ç1	Ç2	Ç3	Ç4	Ç5	Ç6	Ç7	Ç8	Ç9	Ç10	Ç11
Bulgaria	358,4714	8762,10	6898	8177	7574	1208	6366	784	6893	7019,812	5775,45
Georgia	235,672	3683,42	3424	3424	3461,39	1189	3461,39	982	6370	3461,39	6370
Greece	818,750	3200,00	1836	3212	2267	1887	7051	1134	2117	3567	7122
Russia	17283,462	18594,98	32796	32796	1009046	16755	84148	58436	34609	100904	404535
Ukraine	6343,768	343433,00	187557	187557	351921	5098	9878	6789	7812	51045	300841

Romania	283,690	40143,00	9186	7255,6	23752	5353	18399	4947	6739	15613	18993
Serbia	151,220	11896,00	3086,6	3231	5439	1448	4342	1033	3113	5248,6	4993
Turkey	282,713	23583,00	10773	10773	19559	14517	4992	14084	5167	19559	19254

Table 4. Matrix Y

4.1.1.2. Normalization of the Matrices

With the help of Eq. 3 and Eq. 4, all elements of both matrices were normalized and normalized matrices were constructed as seen in Eq. 3a and 3b.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
Bulgaria	0,107	0,208	0,075	0,045	0,218	0,025	0,048	0,534	0,042	0,029	0,035	0,050	0,030	0,015	0,011
Georgia	0,143	0,014	0,037	0,016	0,004	0,003	0,023	0,049	0,021	0,010	0,009	0,018	0,018	0,011	0,001
Greece	0,036	0,042	0,025	0,476	0,041	0,045	0,037	0,014	0,008	0,016	0,015	0,010	0,013	0,019	0,001
Russia	0,107	0,056	0,024	0,019	0,129	0,886	0,613	0,138	0,643	0,613	0,463	0,465	0,856	0,652	0,887
Ukraine	0,071	0,069	0,020	0,049	0,138	0,012	0,033	0,079	0,151	0,155	0,255	0,297	0,021	0,242	0,068
Romania	0,107	0,069	0,351	0,164	0,136	0,019	0,112	0,097	0,059	0,077	0,128	0,090	0,001	0,018	0,013
Serbia	0,214	0,222	0,233	0,025	0,119	0,004	0,086	0,029	0,019	0,027	0,028	0,024	0,025	0,010	0,008
Turkey	0,214	0,319	0,235	0,206	0,216	0,007	0,049	0,061	0,057	0,073	0,068	0,046	0,036	0,031	0,011

Table 5. Matrix X^*

	I16	I17	I18	I19	I20	I21	I22
Bulgaria	0,019	0,014	0,019	0,464	0,017	0,051	0,008
Georgia	0,010	0,006	0,010	0,021	0,050	0,062	0,033
Greece	0,001	0,011	0,002	0,005	0,008	0,101	0,037
Russia	0,704	0,655	0,743	0,104	0,242	0,160	0,172
Ukraine	0,217	0,171	0,140	0,298	0,496	0,177	0,006
Romania	0,014	0,088	0,064	0,061	0,102	0,281	0,284
Serbia	0,014	0,013	0,011	0,013	0,026	0,064	0,025
Turkey	0,021	0,042	0,010	0,034	0,057	0,104	0,434

Table 5. Matrix X^* Continue

	Ç1	Ç2	Ç3	Ç4	Ç5	Ç6	Ç7	Ç8	Ç9	Ç10	Ç11
Bulgaria	0,014	0,019	0,027	0,032	0,005	0,025	0,046	0,009	0,095	0,034	0,008
Georgia	0,009	0,008	0,013	0,013	0,002	0,025	0,025	0,011	0,087	0,017	0,008
Greece	0,032	0,007	0,007	0,013	0,002	0,040	0,051	0,013	0,029	0,017	0,009
Russia	0,671	0,041	0,128	0,128	0,709	0,353	0,607	0,663	0,475	0,489	0,527
Ukraine	0,246	0,758	0,734	0,731	0,247	0,107	0,071	0,077	0,107	0,247	0,392
Romania	0,011	0,089	0,036	0,028	0,017	0,113	0,133	0,056	0,093	0,076	0,025
Serbia	0,006	0,026	0,012	0,013	0,004	0,031	0,031	0,012	0,043	0,025	0,007
Turkey	0,011	0,052	0,042	0,042	0,014	0,306	0,036	0,160	0,071	0,095	0,025

Table 6. Matrix Y^*

4.1.1.3. Construction of the Entropy Matrices

By using Eq 6a and 6b, entropy values of all elements of each matrix were calculated and entropy matrices, which shows entropy values of input and output factors were constructed.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
Bulgaria	-0,24	-0,33	-0,19	-0,14	-0,33	-0,09	-0,15	-0,34	-0,13	-0,10	-0,12	-0,15	-0,11	-0,06	-0,05
Georgia	-0,28	-0,06	-0,12	-0,07	-0,02	-0,02	-0,09	-0,15	-0,08	-0,05	-0,04	-0,07	-0,07	-0,05	0,00
Greece	-0,12	-0,13	-0,09	-0,35	-0,13	-0,14	-0,12	-0,06	-0,04	-0,07	-0,06	-0,05	-0,06	-0,08	-0,01
Russia	-0,24	-0,16	-0,09	-0,08	-0,26	-0,11	-0,30	-0,27	-0,28	-0,30	-0,36	-0,36	-0,13	-0,28	-0,11
Ukraine	-0,19	-0,19	-0,08	-0,15	-0,27	-0,05	-0,11	-0,20	-0,29	-0,29	-0,35	-0,36	-0,08	-0,34	-0,18
Romania	-0,24	-0,19	-0,37	-0,30	-0,27	-0,07	-0,25	-0,23	-0,17	-0,20	-0,26	-0,22	-0,01	-0,07	-0,06
Serbia	-0,33	-0,33	-0,34	-0,09	-0,25	-0,02	-0,21	-0,10	-0,07	-0,10	-0,10	-0,09	-0,09	-0,05	-0,04
Turkey	-0,33	-0,36	-0,34	-0,33	-0,33	-0,03	-0,15	-0,17	-0,16	-0,19	-0,18	-0,14	-0,12	-0,11	-0,05
Ej	0,89	0,80	0,74	0,68	0,86	0,24	0,62	0,69	0,56	0,59	0,67	0,65	0,30	0,47	0,23
Dj=1-Ej	0,11	0,20	0,26	0,32	0,14	0,76	0,38	0,31	0,44	0,41	0,33	0,35	0,70	0,53	0,77
Wj	0,01	0,02	0,03	0,04	0,02	0,09	0,04	0,04	0,05	0,05	0,04	0,04	0,08	0,06	0,09

Table 7. Matrix E^*

	I16	I17	I18	I19	I20	I21	I22
Bulgaria	-0,07	-0,06	-0,08	-0,36	-0,07	-0,15	-0,04
Georgia	-0,05	-0,03	-0,05	-0,08	-0,15	-0,17	-0,11
Greece	0,00	-0,05	-0,01	-0,03	-0,04	-0,23	-0,12
Russia	-0,25	-0,28	-0,22	-0,24	-0,34	-0,29	-0,30
Ukraine	-0,33	-0,30	-0,28	-0,36	-0,35	-0,31	-0,03
Romania	-0,06	-0,21	-0,18	-0,17	-0,23	-0,36	-0,36
Serbia	-0,06	-0,06	-0,05	-0,05	-0,10	-0,18	-0,09
Turkey	-0,08	-0,13	-0,05	-0,11	-0,16	-0,24	-0,36
Ej	0,41	0,51	0,41	0,64	0,66	0,88	0,65
Dj=1-Ej	0,59	0,49	0,59	0,36	0,34	0,12	0,35
Wj	0,07	0,06	0,07	0,04	0,04	0,01	0,04

Table 7. Matrix E^* Continue

Afterward, Entropy matrix E^- for output factors were constructed as seen in Table 8.

	Ç1	Ç2	Ç3	Ç4	Ç5	Ç6	Ç7	Ç8	Ç9	Ç10	Ç11
Bulgaria	-0,06	-0,08	-0,10	-0,11	-0,03	-0,09	-0,14	-0,04	-0,22	-0,11	-0,04
Georgia	-0,04	-0,04	-0,06	-0,06	-0,01	-0,09	-0,09	-0,05	-0,21	-0,07	-0,04
Greece	-0,11	-0,03	-0,04	-0,05	-0,01	-0,13	-0,15	-0,06	-0,10	-0,07	-0,04
Russia	-0,27	-0,13	-0,26	-0,26	-0,24	-0,37	-0,30	-0,27	-0,35	-0,35	-0,34
Ukraine	-0,35	-0,21	-0,23	-0,23	-0,35	-0,24	-0,19	-0,20	-0,24	-0,35	-0,37

Romania	-0,05	-0,21	-0,12	-0,10	-0,07	-0,25	-0,27	-0,16	-0,22	-0,20	-0,09
Serbia	-0,03	-0,10	-0,05	-0,06	-0,02	-0,11	-0,11	-0,05	-0,13	-0,09	-0,03
Turkey	-0,05	-0,15	-0,13	-0,13	-0,06	-0,36	-0,12	-0,29	-0,19	-0,22	-0,09
Ej	0,43	0,43	0,45	0,46	0,36	0,74	0,62	0,51	0,76	0,66	0,47
Dj=1-Ej	0,57	0,57	0,55	0,54	0,64	0,26	0,38	0,49	0,24	0,34	0,53
Wj	0,11	0,11	0,11	0,11	0,13	0,05	0,07	0,10	0,05	0,07	0,10

Table 8. Matrix E^-

4.1.1.4. Calculation of the Weight Values of the Input&Output Factors

As shown above in Table 7 and 8, weight values (Wj) of all input and output factors were computed and determined by using Eq. 10a and 10b.

4.1.1.5. Construction of Decision Matrices

Input and output matrices that constructed in the first step of the model were used as is.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
Bulgaria	3	15	38	4	219	391	69	8.177	2.868	4.029	6.475	4.726	11.490	1.596	9.636
Georgia	4	1	19	2	4	44	33	753	1.415	1.415	1.644	1.644	6.705	1.213	457
Greece	1	3	13	47	41	714	53	217	520	2.240	2.764	933	4.936	2.089	672
Russia	3	4	12	2	130	13.997	879	2.118	43.621	85.375	85.375	43.621	327.590	70.040	744.275
Ukraine	2	5	10	5	139	190	47	1.213	10.277	21.603	46.997	27.835	7.889	26.011	56.890
Romania	3	5	179	16	137	295	161	1.480	4.030	10.766	23.568	8.473	483	1.969	11.165
Serbia	6	16	119	2	120	60	123	440	1.279	3.736	5.082	2.263	9.505	1.115	6.347
Turkey	6	23	120	20	217	106	70	928	3.856	10.131	12.532	4.350	13.953	3.372	9.377

Table 9. Matrix X

	I16	I17	I18	I19	I20	I21	I22
Bulgaria	21.308	174	235	269.538	269.538	0,40	993.934
Georgia	11.871	81	124	12.448	777.724	0,49	3.946.779
Greece	672	143	30	3.158	129.081	0,80	4.340.992
Russia	807.384	8.402	9.098	60.295	3.765.077	1,26	20.425.497
Ukraine	248.947	2.195	1.720	173.370	7.714.275	1,40	728.577
Romania	16.168	1.128	784	35.553	1.583.395	2,22	33.647.094
Serbia	15.853	170	133	7.277	411.158	0,51	2.969.601
Turkey	24.127	543	125	19.570	891.326	0,82	51.482.084

Table 9. Matrix X Continue

	Ç1	Ç2	Ç3	Ç4	Ç5	Ç6	Ç7	Ç8	Ç9	Ç10	Ç11
Bulgaria	358,4714	8762,10	6898	8177	7574	1208	6366	784	6893	7019,812	5775,45
Georgia	235,672	3683,42	3424	3424	3461,39	1189	3461,39	982	6370	3461,39	6370
Greece	818,750	3200,00	1836	3212	2267	1887	7051	1134	2117	3567	7122
Russia	17283,462	18594,98	32796	32796	1009046	16755	84148	58436	34609	100904	404535
Ukraine	6343,768	343433,00	187557	187557	351921	5098	9878	6789	7812	51045	300841
Romania	283,690	40143,00	9186	7255,6	23752	5353	18399	4947	6739	15613	18993
Serbia	151,220	11896,00	3086,6	3231	5439	1448	4342	1033	3113	5248,6	4993
Turkey	282,713	23583,00	10773	10773	19559	14517	4992	14084	5167	19559	19254

Table 10. Matrix Y

4.1.1.6. Normalization of the Decision Matrices

Elements of decision matrices were normalized by using Eq. 11a and 11b. While Matrix R represents input factors (Eq. 12a), Matrix S is constructed for output factors (Eq. 12b).

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
Bulgaria	0,274	0,455	0,152	0,081	0,538	0,028	0,076	0,934	0,063	0,045	0,064	0,089	0,035	0,021	0,013
Georgia	0,365	0,030	0,076	0,030	0,011	0,003	0,036	0,086	0,031	0,016	0,016	0,031	0,020	0,016	0,001
Greece	0,091	0,091	0,052	0,867	0,101	0,051	0,058	0,025	0,011	0,025	0,027	0,018	0,015	0,028	0,001
Russia	0,274	0,121	0,048	0,035	0,318	0,998	0,965	0,242	0,963	0,954	0,842	0,824	0,997	0,935	0,997
Ukraine	0,183	0,152	0,040	0,089	0,340	0,014	0,051	0,139	0,227	0,241	0,463	0,526	0,024	0,347	0,076
Romania	0,274	0,152	0,714	0,298	0,336	0,021	0,177	0,169	0,089	0,120	0,232	0,160	0,001	0,026	0,015
Serbia	0,548	0,486	0,475	0,045	0,295	0,004	0,135	0,050	0,028	0,042	0,050	0,043	0,029	0,015	0,009
Turkey	0,548	0,698	0,479	0,376	0,533	0,008	0,077	0,106	0,085	0,113	0,124	0,082	0,042	0,045	0,013

Table 11. Matrix R

	I16	I17	I18	I19	I20	I21	I22
Bulgaria	0,025	0,020	0,025	0,819	0,031	0,125	0,015
Georgia	0,014	0,009	0,013	0,038	0,088	0,150	0,061
Greece	0,001	0,016	0,003	0,010	0,015	0,246	0,067
Russia	0,954	0,957	0,978	0,183	0,427	0,391	0,314
Ukraine	0,294	0,250	0,185	0,527	0,874	0,433	0,011
Romania	0,019	0,128	0,084	0,108	0,179	0,687	0,516
Serbia	0,019	0,019	0,014	0,022	0,047	0,157	0,046
Turkey	0,029	0,062	0,013	0,059	0,101	0,254	0,790

Table 11. Matrix R Continue

	Ç1	Ç2	Ç3	Ç4	Ç5	Ç6	Ç7	Ç8	Ç9	Ç10	Ç11
Bulgaria	0,019	0,025	0,036	0,043	0,007	0,051	0,073	0,013	0,182	0,060	0,011
Georgia	0,013	0,011	0,018	0,018	0,003	0,050	0,040	0,016	0,168	0,030	0,013
Greece	0,044	0,009	0,010	0,017	0,002	0,080	0,081	0,019	0,056	0,031	0,014
Russia	0,937	0,054	0,172	0,172	0,944	0,711	0,961	0,962	0,914	0,868	0,801
Ukraine	0,344	0,989	0,981	0,981	0,329	0,216	0,113	0,112	0,206	0,439	0,596
Romania	0,015	0,116	0,048	0,038	0,022	0,227	0,210	0,081	0,178	0,134	0,038
Serbia	0,008	0,034	0,016	0,017	0,005	0,061	0,050	0,017	0,082	0,045	0,010
Turkey	0,015	0,068	0,056	0,056	0,018	0,616	0,057	0,232	0,136	0,168	0,038

Table 12. Matrix S

4.1.1.7. Calculation of Distance Measures of Input&Output Factors

The distance measure of each input factors was calculated with the help of eq 13b.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
Bulgaria	1,093	1,245	1,226	1,223	1,198	1,263	1,217	1,121	1,109	1,057	1,000	1,081	1,214	1,176	1,171
Georgia	1,169	2,179	1,289	1,268	1,262	1,352	1,252	1,142	1,122	1,083	1,020	1,107	2,033	1,206	1,296
Greece	1,130	1,331	1,257	1,239	1,214	1,294	1,238	1,137	1,109	1,072	1,009	1,095	1,252	1,264	1,321
Russia	1,151	1,270	1,237	1,248	1,225	1,281	1,232	1,149	1,110	1,058	1,016	1,084	1,223	1,191	1,417
Ukraine	2,059	1,487	2,189	2,177	2,040	2,087	2,215	2,056	2,105	2,012	1,957	2,060	1,397	1,603	1,562
Romania	1,145	1,384	1,453	1,465	1,661	1,789	1,241	1,468	1,185	1,352	1,250	1,266	1,741	2,050	1,604
Serbia	1,270	1,414	1,315	1,343	1,430	1,423	1,219	1,147	1,124	1,077	1,128	1,166	1,322	1,355	1,858
Turkey	1,229	1,296	1,254	1,265	1,248	1,306	1,246	1,136	1,117	1,076	1,019	1,096	1,236	1,223	1,328

Table 13. Matrix T

	I16	I17	I18	I19	I20	I21	I22
Bulgaria	1,233	1,357	1,362	1,000	1,000	1,000	1,000
Georgia	1,248	1,376	1,387	1,036	1,043	1,007	1,051
Greece	1,293	1,370	1,373	1,018	1,018	1,003	1,050
Russia	1,299	1,401	1,371	1,010	1,017	1,002	1,080
Ukraine	1,546	2,294	1,416	1,172	1,172	1,944	1,711
Romania	1,244	1,701	2,351	1,981	1,981	1,329	1,216
Serbia	1,749	1,372	1,478	1,048	1,038	1,022	1,227
Turkey	1,278	1,365	1,396	1,016	1,017	1,005	1,061

Table 13. Matrix T Continue

	Ç1	Ç2	Ç3	Ç4	Ç5	Ç6	Ç7	Ç8	Ç9	Ç10	Ç11
Bulgaria	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Georgia	1,073	1,013	1,182	1,060	1,011	1,000	1,000	1,000	1,000	1,000	1,000
Greece	1,040	1,016	1,168	1,030	1,013	1,000	1,000	1,000	1,000	1,000	1,000
Russia	1,081	1,019	1,056	1,031	1,014	1,000	1,000	1,000	1,000	1,000	1,000
Ukraine	1,961	1,962	1,914	1,868	1,801	1,000	1,000	1,000	1,000	1,000	1,000
Romania	1,113	1,112	1,206	1,439	1,596	1,000	1,000	1,000	1,000	1,000	1,000
Serbia	1,210	1,081	1,178	1,134	1,038	1,000	1,000	1,000	1,000	1,000	1,000
Turkey	1,050	1,017	1,082	1,045	1,010	1,000	1,000	1,000	1,000	1,000	1,000

Table 14. Matrix U

Distance measure values were multiplied by weight values of factors that calculated in the first four steps and distance measure values were weighted.

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11	I12	I13	I14	I15
Bulgaria	0,014	0,033	0,033	0,038	0,025	0,087	0,044	0,067	0,052	0,048	0,039	0,042	0,081	0,060	0,089
Georgia	0,015	0,023	0,031	0,036	0,016	0,085	0,043	0,037	0,051	0,047	0,037	0,040	0,080	0,059	0,088
Greece	0,012	0,024	0,030	0,066	0,018	0,089	0,043	0,035	0,050	0,047	0,038	0,039	0,080	0,060	0,088
Russia	0,014	0,025	0,030	0,036	0,021	0,170	0,082	0,043	0,097	0,090	0,068	0,071	0,157	0,114	0,175
Ukraine	0,013	0,026	0,030	0,038	0,022	0,086	0,043	0,039	0,061	0,057	0,054	0,059	0,080	0,079	0,094
Romania	0,014	0,026	0,049	0,046	0,022	0,087	0,048	0,040	0,054	0,051	0,045	0,045	0,079	0,060	0,089
Serbia	0,017	0,034	0,042	0,037	0,021	0,085	0,047	0,036	0,051	0,048	0,039	0,040	0,081	0,059	0,088
Turkey	0,017	0,038	0,043	0,048	0,025	0,086	0,044	0,038	0,054	0,051	0,041	0,042	0,082	0,061	0,089

Table 15. Matrix I

	I16	I17	I18	I19	I20	I21	I22
Bulgaria	0,068	0,056	0,068	0,074	0,039	0,014	0,040
Georgia	0,067	0,055	0,067	0,042	0,042	0,014	0,042
Greece	0,066	0,056	0,066	0,041	0,039	0,016	0,042
Russia	0,130	0,107	0,131	0,048	0,055	0,018	0,052
Ukraine	0,086	0,068	0,078	0,062	0,072	0,018	0,040
Romania	0,068	0,062	0,072	0,045	0,045	0,022	0,060
Serbia	0,068	0,056	0,067	0,041	0,040	0,015	0,041
Turkey	0,068	0,058	0,067	0,043	0,042	0,016	0,071

Table 15. Matrix I Continue

	Ç1	Ç2	Ç3	Ç4	Ç5	Ç6	Ç7	Ç8	Ç9	Ç10	Ç11
Bulgaria	0,009	0,004	0,006	0,007	0,008	0,017	0,008	0,005	0,013	0,013	0,022
Georgia	0,008	0,002	0,004	0,004	0,007	0,017	0,006	0,005	0,012	0,011	0,022
Greece	0,012	0,002	0,003	0,004	0,007	0,019	0,009	0,005	0,007	0,011	0,022
Russia	0,111	0,007	0,021	0,020	0,126	0,050	0,074	0,096	0,047	0,066	0,104
Ukraine	0,045	0,111	0,108	0,107	0,049	0,025	0,011	0,014	0,014	0,038	0,082
Romania	0,009	0,014	0,007	0,006	0,010	0,026	0,018	0,011	0,012	0,018	0,024
Serbia	0,008	0,005	0,004	0,004	0,008	0,018	0,007	0,005	0,008	0,012	0,022
Turkey	0,009	0,009	0,008	0,008	0,009	0,045	0,007	0,026	0,010	0,020	0,025

Table 16. Matrix N

4.1.1.8. Calculation of Performance Scores

For each decision option, the sum values of the weighted distance measure of both input and output factors were computed separately. The obtained input value for each decision option is divided into the sum of the output values of the same option by using eq 15 and performance score is calculated for each decision alternative.

	Input Value	Output Value	Performance Score	Rank
Bulgaria	1,1115	0,1108	0,0997	5
Georgia	1,0175	0,0986	0,0969	6
Greece	1,0453	0,1006	0,0962	7
Russia	1,7348	0,7218	0,4160	2
Ukraine	1,2065	0,6047	0,5012	1
Romania	1,1284	0,1561	0,1383	4
Serbia	1,0524	0,0988	0,0939	8
Turkey	1,1243	0,1762	0,1567	3

Table 17

5. RESULTS

Proposed hybrid multi-criteria decision-making model reveals that Ukraine is the best performance in general. Although the source using of this country is very rational and acceptable obtained output is under the output score of Russia. More importantly, Ukraine could reach to higher efficiency value by using lower input factors compared to Russia. Essentially, it can be seen that Russian rail freight system has higher output value than others. Except for Russia, input values of all countries almost similar and there is little difference among them when other countries final input scores are reviewed. On the other hand, there are serious differences among their output scores. It is clearly seen that the output scores of countries were determined final performance score and ranking of each country. Input scores of countries are not determinative in aspects of results and these scores are very closer more or less. Therefore, countries should focus on outputs, which is reachable in short or middle terms, related to own rail freight transportation activities in order to improve their rail freight transport performance.

When the relative importance values of the input factors are evaluated, the most important input factor is the criterion called mean annual staff strength in management. Its importance value is recorded as 88

per thousand. In terms of thousand train-km, the output factor called the freight train movements on the network is determined as the most important output factor in the aspect of railway performance of countries. Graphic for relative importance value of each input and output factors can be seen in fig 2.

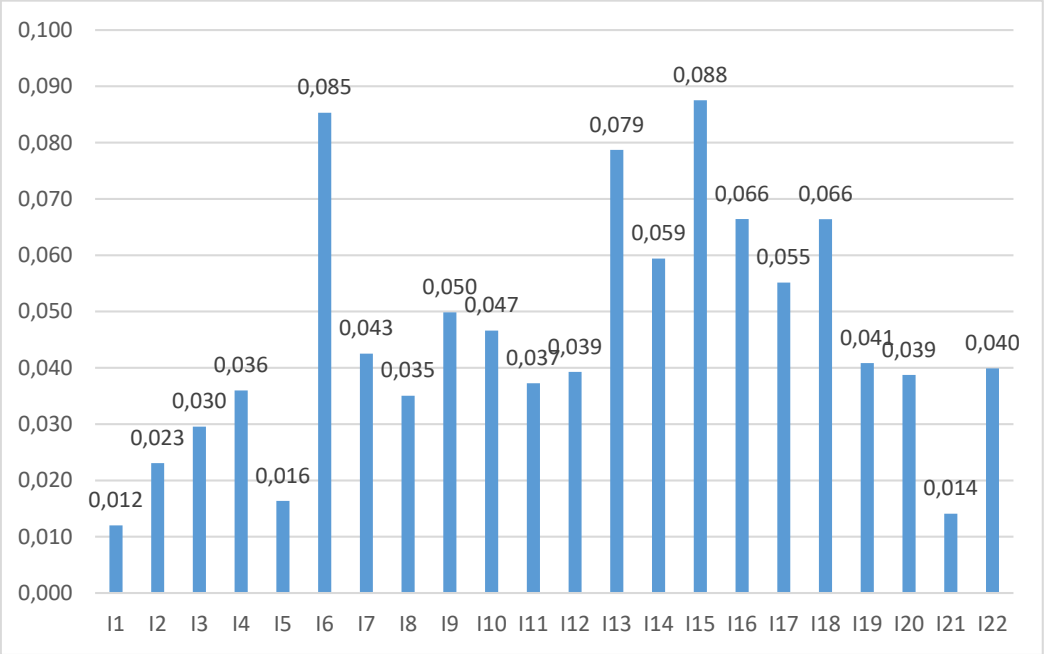


Fig. 2. Importance Score of Input Factors

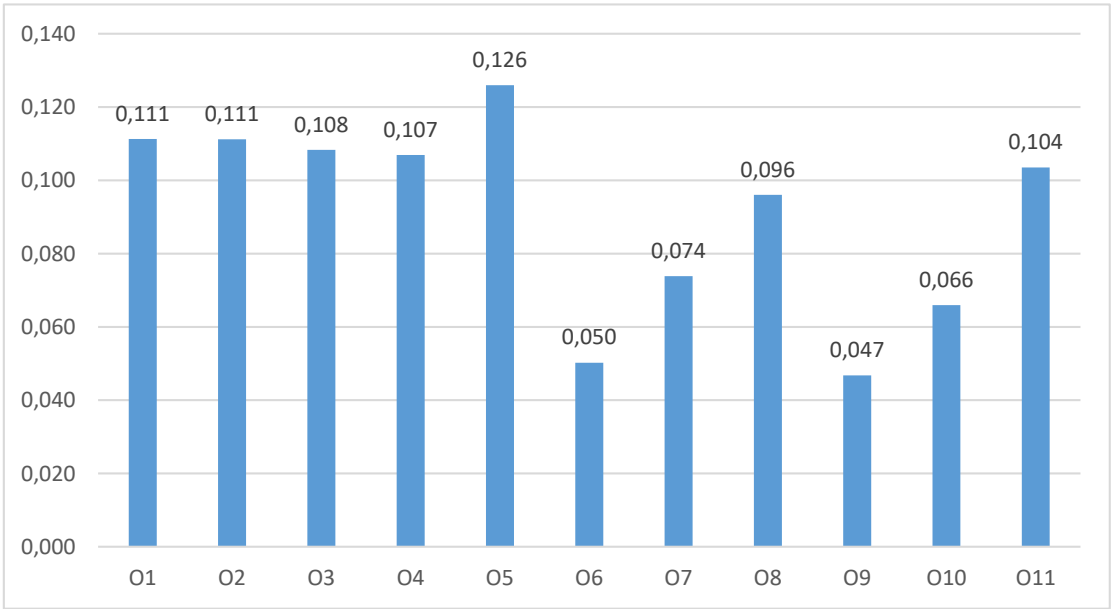


Fig. 3. Importance Score of Output Factors

Findings of this study revealed that the railway freight transport performances of Ukraine and Russia are higher than the other and efficiency scores of both countries can incomparably. Especially, Bulgaria, Turkey, Greece have seriously low efficiency and they have to take some measures, which focus on improvement own rail freight performance. These countries should focus on increasing output factors

to improve own performance instead of reducing the input factors that using for carrying out freight transport operations.

As a result, these countries can make investments and source utilization in a more rational basis. As seen in the outputs and results of this study, making an investment at a higher level does not mean the higher performance and productivity.

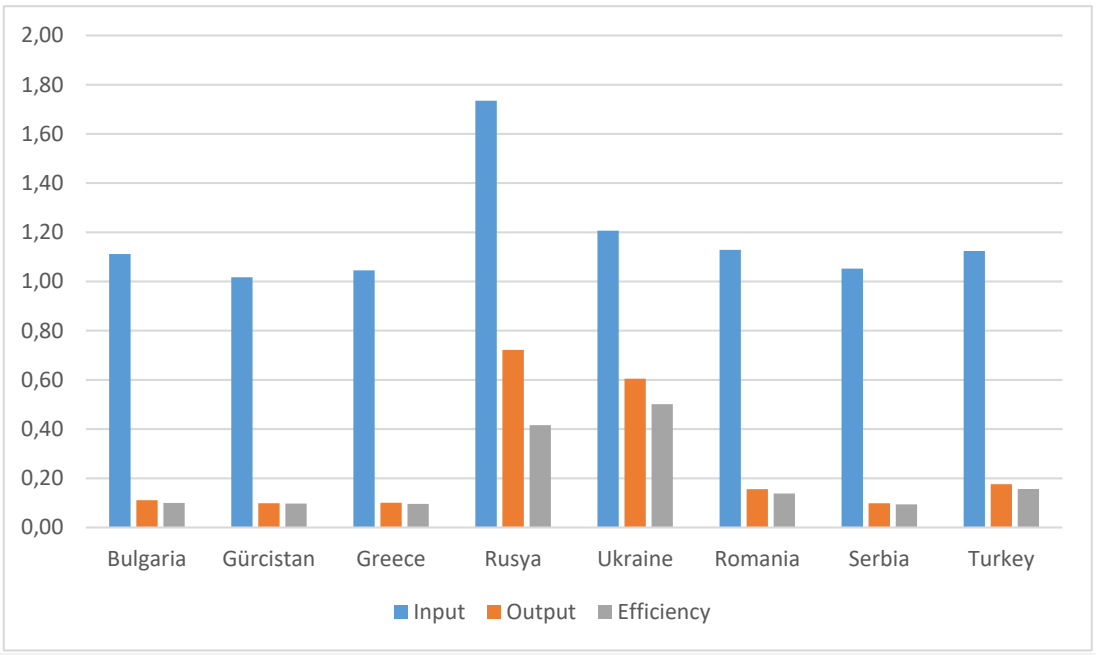


Fig. 4. Performance, Input and Output Scores of the Countries

6. DISCUSSION

When obtained results of this paper are discussed, it can be seen that Ukraine has the best performance in rail freight transportation. This finding can be accepted as realistic because railway systems of this country are very advanced compared to the others. More importantly, the focal point of these countries in aspect of transportation policy is railway transportation and it has given more importance to this kind of transportation modes than other Black sea countries. Though this country has a wide railway network and huge rail fleet, it continues to make investments to these fields. Only, Russia has also shown a good performance, but its performance is not closer to performance value related to railway freight transportation of Ukraine. Even if relative performance scores of these countries in aspects of the input factors, their performance scores for outputs are extremely different. If a country wants to improve own railway freight transport performance, it has to focus on own outputs than own input factors.

7. CONCLUSIONS

The suggested model that consists of entropy and EATWIOS method is evaluated in this paper. This research verified that it is working to make an effective performance analysis of the rail freight systems. Obtained results have shown that performance scores of the decision options are coherent to expectations of experts about these countries rail freight systems. In addition to that, obtained values of input and output factors have clearly shown that some variables have more importance and are coherent to the obtained results. When it is summarized, the proposed model may be a useful tool for performance analysis and it can also be used in various fields such as business, international trade, marketing and so on. Therefore, it may be a guide to researches and studies, which will be realized in the future and it can be used in these studies as a useful multi-criteria decision-making model.

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