Erzincan Üniversitesi
Fen Bilimleri Enstitüsü Dergisi
2018, 11(2), 243-254
ISSN: 1307-9085, e-ISSN: 2149-4584
Erzincan University
Journal of Science and Technology
2018, 11(2), 243-254
DOI: 10.18185/erzifbed.390010

Evaluation of Wastewater Treatment Performances for Municipalities by Using MCDM Methods: Case Study in Turkey

Ertuğrul Ayyıldız[1*], Gökhan Özçelik[2]

[1]Yıldız Technical University, Department of Industrial Engineering, İstanbul, Turkey

[2]Karadeniz Technical University, Department of Industrial Engineering, Trabzon, Turkey

Geliş / Received: 04/02/2018, Kabul / Accepted: 13/07/2018

Abctract
Reusing of the wastewater has a vital importance because of limited natural water resources all around the world. Recycled wastewater can be used in many areas such as agriculture, industry, cleaning etc. Treatment of wastewater is one of the important tasks of metropolitan municipalities. The aim of this study is to evaluate the performances of wastewater treatment services provided by the metropolitan municipalities in Turkey using a hybrid approach using Entropy, SAW, MOORA and TOPSIS methods. In the scope of the study, four criteria have been considered as the ratio of the municipal population served by the treatment plant to the total population, the ratio of the municipal population served by the sewerage system to the total population, treatment rate of discharged water, increase rate of treated water in treatment plants. A case study has been conducted in Turkey and the metropolitan municipalities have been ranked depending on their performance. Aydin Metropolitan Municipality as the highest municipality and Kahramanmaraş Metropolitan Municipality as the lowest municipality have been determined. In Western cities performance is high, performance goes down as it goes east.

Keywords: Wastewater treatment, Entropy, SAW, TOPSIS, MOORA

Belediyelerin Atıksu Arıtma Performanslarının ÇKKV Yöntemleri Kullanılarak Değerlendirilmesi: Türkiye Örneği

Öz
Atıksuyun yeniden kullanımı, tüm dünyadaki sınırlı doğal su kaynakları nedeniyle hayati öneme sahiptir. Geri dönüştürelen atıksu, tarım, sanayi, temizlik vb. birçok alanda kullanılabilir. Atık suyun arıtımı, büyükşehir belediyelerinin önemli görevlerinden biridir. Bu çalışmanın amacı, Türkiye'deki büyükşehir belediyeleri tarafından sağlanan atıksu arıtma hizmetlerinin Entropi, SAW, MOORA ve TOPSIS yöntemlerini kullanan hibrit bir yaklaşımla performanslarını değerlendirmektir. Çalışma kapsamında, arıtma tesisleri ile hizmet verilen belediye nüfusunun toplam nüfusa oranı, kanalizasyon sistemi ile hizmet verilen belediye nüfusunun toplam nüfusa oranı, boşaltılan suyun arıtılma oranı ve arıtma tesislerinde arıtılmış su oranı olmak üzere dört kriter dikkate alınmıştır. Türkiye'de bir vaka çalışması yapılmış ve büyükşehir belediyeleri performanslarına göre sıralanmıştır. Performansı en yüksek belediye olarak Aydın Büyükşehir Belediyesi en düşük belediye olarak ise Kahramanmaraş Büyükşehir Belediyesi tespit edilmiştir. Batı şehirlerinde performanslar yüksek iken, doğuya gidildikçe performans düşmektedir.

Anahtar Kelimeler: Atıksu arıtımı, Entropi, SAW, TOPSIS, MOORA

1. Introduction

The reuse of wastewater and keeping resources clean is becoming important due to the increasing population, developing industry and rapid increase of water demand. The main reasons of using the wastewater recycling were indicated in Ministry of Labor and Social Security report (Ozcan, 2014) are shown as below:

- To allocate limited natural water resources for aims requiring qualified water,

*Corresponding to: ertugrulayyildiz@ktu.edu.tr

- To prevent environmental pollution problems that may be caused by waste water discharges,
- Since domestic wastewater contains 99.9 % pure water,
- Concentration of water requirements at certain centers due to the increase of urban population shares.

Wastewater recycled through wastewater treatment plants can be used in agricultural, industrial, resource feeding, fire water, recycling in toilets, even as drinking water. For this reason, it is very important to recycle the waste water taking consider of the decreasing water resources.

In the literature this issue is well studied. Ishikawa and Kusuda (1996) presented and discussed a probabilistic approach for evaluation of the performance of the urban wastewater systems. Moreover, they calculated net present cost when they were trying to find best option. A simple multi-criteria approach, known as WISPS (wastewater integrated system performance score) has been applied in a theoretical study using actual data to decide which of the four catchments in a Scottish water authority area should be prioritized for improvement in Blackwood et al. (2000)'s study. Volcke et al. studied about the simulation Benchmark multi criteria evaluation of the performance of control strategies for biological wastewater treatment plants.

Reviewed the literature for sustainability of the wastewater treatments. Palme et al.(2005) presented a study where sustainable development indicators for sludge handling and wastewater treatment systems were constructed in co-operation with a large Swedish water company. They used multi-criteria analysis (MCA) and life cycle assessment (LCA). Hidalgo et al. (2007) presented the MCA user friendly software that able to guide the responsible authorities to the most efficient solutions in terms of can be sustainable for the possibilities agricultural reuse of the water. Flores-Alsina et al. (2008)'s study showed the variations in the decision making when there is an uncertainty in activated sludge model (ASM) parameters is either included or not during the evaluation of wastewater treatment plant control strategies. Karagiannidis and Perkoulidis (2009) described a conceptual framework and methodological tool developed for the evaluation of different anaerobic digestion technologies suitable for treating the organic fraction of municipal solid waste by introducing the multi-criteria decision support method Electre III and demonstrating its related applicability via a test application. Benedetti et al. used MCA of wastewater treatment plant design and control scenarios under uncertainty. Bottero, et al. (2011) studied the application of different MCA techniques (Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) for a real decision problem concerning the choice of the mostsustainable wastewater treatment techno logy. Kimet al. (2013) developed a new framework that prioritized the best sites for treated wastewater instream using fuzzy Technique for Order of Preference by Similarity to Ideal Solution (fuzzy TOPSIS).Ranade and Bhandari (2014) have prepared a comprehensive book on industrial wastewater treatment. They also used a complex multi-criteria decision support tool that is called ELECTRE in their study. Ouyang et al. combined fuzzy AHP with multidimensional scaling (MDS) approach to improve current methods for determining the optimal alternative and the combined method was applied to select natural wastewater treatment alternatives in a case study.

Although there is a lot of work in the literature in the literature, the method proposed in this study has not been used before. For this reason, it can be said that this work is original. The aim of the study is to evaluate the performance of the wastewater treatment services provided by the existing metropolitan municipalities in Turkey. For this purpose, the problem has been taken into consideration as a Multi-Criteria Decision-Making (MCDM) problem. In the study, because only metropolitan municipalities have been investigated in Turkey, they have been considered as alternatives in MCDM problem. Moreover, the performances of wastewater treatment services provided by these cities have been evaluated depending on four main criteria. These are the ratio of the municipal population served by the treatment plant to the total population, the ratio of the municipal population served by the sewerage system to the total population, treatment rate of discharged water and increase rate of treated water in treatment plants.

The remainder of the study is organized as follows. In the next section, the methodology related to the handled methods has been presented. Moreover, a case study has been carried out about the evaluation of the performances of wastewater treatment services provided by the metropolitan municipalities in Turkey explaining on the methods. In third section, findings can be seen. Finally, the study has been concluded in Section 4.

2. Material and Method

In the study, a hybrid approach has been presented for the evaluation of the performances of wastewater treatment services provided by the metropolitan municipalities in Turkey. In this context, entropy has been integrated with SAW, MOORA and TOPSIS that are MCDM methods. In this approach, while entropy is used for determining the weights of the considered criteria, SAW, MOORA and TOPSIS are used for evaluation the performances. The cause of considering the three different MCDM methods is to see whether the similar results are obtained. In other words, it is aimed to support to the obtained results in terms of the handled methods. The scheme of the proposed hybrid approach is shown in Figure 1.

In case study, the latest data that was taken from TUIK (2014) on wastewater treatment facilities which located in environmental statistics has been taken into consideration. First of all, the criteria weights of the wastewater treatment services of the thirty metropolitan municipalities have been determined via entropy method. Then, the performances of the metropolitan municipalities have been evaluated with the help of the proposed hybrid approach that these weights have been used in SAW, MOORA and TOPSIS methods. In the next subsections, the considered methods are briefly explained.

2.1. Entropy

While solving MCDM problems, many methods can be used for determining the weights of the criteria. One of these methods is the entropy method which weights the criteria objectively. This method, developed on the concept of entropy, which measures the uncertainty of information in terms of probability theory, is adapted to the information theory. According to the theory, the quality and quantity of information play a key role in any decision making problem (Shabmardan and Zadeb, 2013). In the weighting of the criteria; the range of values that any criterion takes for alternatives is important.

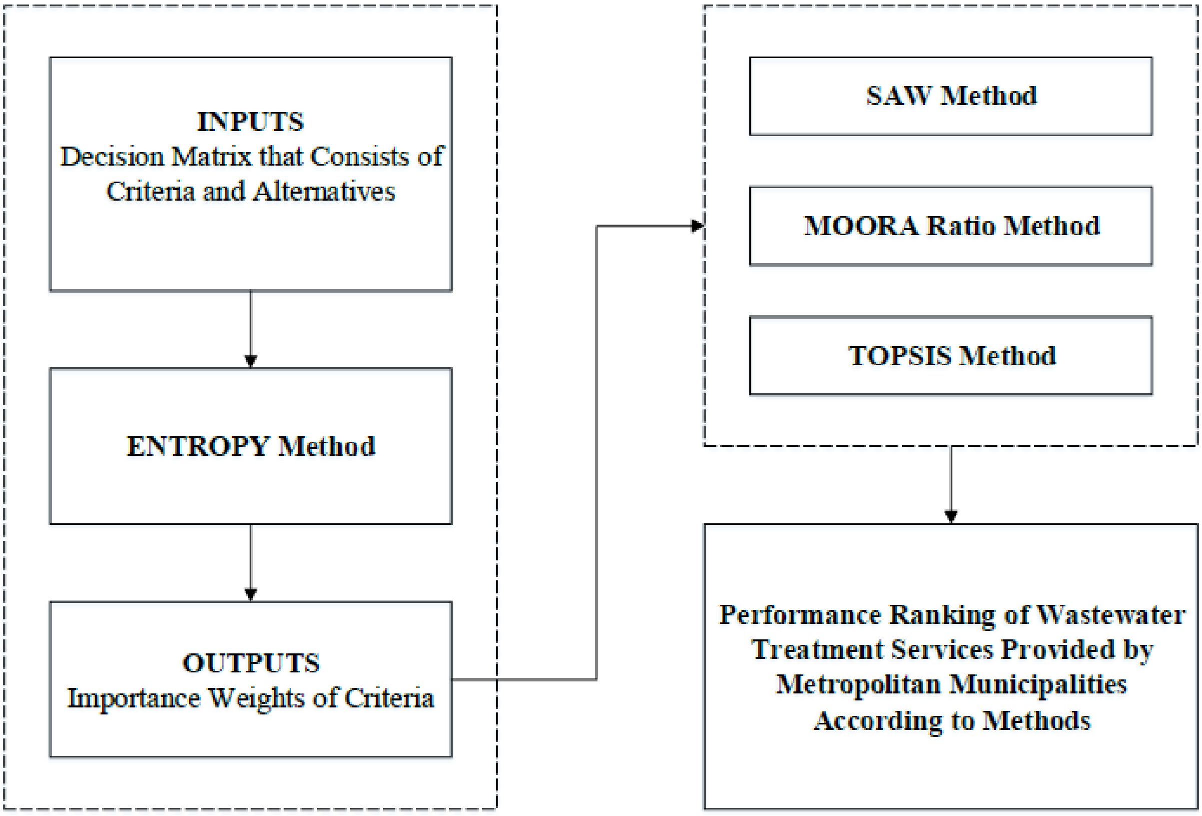

Figure 1. The proposed hybrid approach

The larger the value range, the more important the content of the criterion. This means that it will have a greater entropy value. This method can be applied if we have enough information and numbers for the criteria (Hwang and Yoon, 2012). Developed as a weight calculation procedure by Wang and Lee (2009), the steps of this method are as follows:

Step 1: Creating of the Decision Matrix

Within the scope of the study, wastewater treatment performance of 30 metropolitan municipalities in Turkey has been examined. Data were collected by determining 4 different criteria as the end result of the researches. All the criteria used in the study are the benefit criteria. The decision matrix used is shown in Table 1.

Criteria 1: The ratio of the municipal population served by the treatment plant to the total population,

Criteria 2: The ratio of the municipal population served by the sewerage system to the total population,

Criteria 3: Treatment rate of discharged water,

Criteria 4: Increase rate of treated water in treatment plants.

Table 1. Decision matrix to problem.

Metropolitan Municipality	**Criteria 1**	**Criteria 2**	**Criteria 3**	**Criteria 4**
Adana	85.00	85.00	100.00	11.58
Ankara	93.00	96.00	96.84	29.92
Antalya	80.00	80.00	100.00	16.10
Aydın	88.40	90.00	98.22	50.79
Balıkesir	61.90	78.00	79.33	21.72
Bursa	88.30	99.00	89.16	0.00
Denizli	65.00	80.00	81.20	34.46
Diyarbakır	72.80	98.00	74.26	3.31
Erzurum	0.10	99.00	0.14	0.00
Eskişehir	83.10	90.00	92.31	30.53
Gaziantep	94.00	98.00	95.91	22.79
Hatay	34.30	80.00	42.81	2.91
Mersin	67.10	82.00	81.77	37.27
İstanbul	97.80	100.00	97.83	25.25
İzmir	93.00	93.00	100.00	12.17
Kayseri	88.10	94.00	93.69	10.60
Kocaeli	98.00	98.00	100.00	17.28
Konya	69.80	90.00	77.60	44.16
Malatya	61.10	75.00	81.52	0.00
Manisa	36.40	92.00	39.53	28.11
Kahramanmaraş	0.00	75.00	0.00	0.00
Mardin	0.00	92.00	0.00	0.00
Muğla	55.30	70.00	79.06	28.58
Ordu	20.60	55.00	37.37	51.74
Sakarya	40.90	60.00	68.08	0.00
Samsun	28.50	69.00	41.35	71.21
Tekirdağ	10.90	78.00	13.95	35.64
Trabzon	38.40	80.00	48.01	17.59
Şanlıurfa	5.10	62.00	8.14	7.08
Van	45.00	80.00	56.25	33.00

Step 2: Normalization of the Decision Matrix

$$r_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \qquad (1)$$

m: Number of the alternatives

n: Number of the criteria

x_{ij}: Value of alternative i for criterion j $(i=1,2..m)$, $(j=1,2..n)$

r_{ij}: Normalized value of alternative i for criterion j $(i=1,2..m)$, $(j=1,2..n)$

Step 3: Calculating of the Entropy Values for Criteria

$$k = (\ln(m))^{-1} \qquad (2)$$

$$e_j = -k\sum_{i=1}^{m} r_{ij}\ln(r_{ij}) \qquad (3)$$

k: Coefficient of the entropy

e_j: Entropy value for criterion j $(j=1,2..n)$

Step 4: Calculating of the Weights of Criteria

$$w_j = \frac{1-e_j}{\sum_{i=1}^{m}(1-e_j)} \quad (4)$$

w_j : Weight of the criterion j $(j=1,2..n)$

In the analysis, the criterion weights related to the handled problem have been found as follows:

$w_1 = 0.2647$, $w_2 = 0.0133$, $w_3 = 0.2276$ and $w_4 = 0.4945$.

2.2. SAW (Simple Additive Weighting) Method

SAW one of the most used MCDM methods because of the mathematical simplicity was developed by Churchman and Ackoff (1954). The steps of this method are as follows (Wu, et al., 2009):

Step 1: Normalization of the Decision Matrix

$$r_{ij} = \begin{Bmatrix} \dfrac{x_{ij}}{\max x_{ij}} \\ \dfrac{\min x_{ij}}{x_{ij}} \end{Bmatrix} \quad (5)$$

m: Number of the alternatives

n: Number of the criteria

x_{ij} :Value of alternative i for criterion j $(i=1,2..m)$, $(j=1,2..n)$

r_{ij} :Normalized value of alternative i for criterion j $(i=1,2..m)$, $(j=1,2..n)$

Step 2: Calculating of the Total Preference Value

$$v_i = \sum_{j=1}^{n} w_j r_{ij} \quad (6)$$

w_j : Weights of the criterion j $(j=1,2..n)$

v_i : Total preference value $(i=1,2..m)$

After calculating of the total preference value for each alternative, the preference order has been determined by sorting the alternatives according to the total preference values from the biggest to the smallest.

2.3. TOPSIS (Technique For Order Preference By Similarity To Ideal Solution) Method

TOPSIS that was developed by Hwang and Yoon (1981) is one of the MCDM methods. It makes it possible to make the best selection among the alternatives. When deciding with the TOPSIS method, it is expected that alternative chosen is close to the ideal solution and is also away from the non-ideal solution (negative ideal). The steps of the method are as follows (Alizadeh et al.).

Step 1: Normalization of the Decision Matrix

The squares of the decision criteria values corresponding to each alternative are calculated, the values of each column are summed and the square root is calculated. Then, this operation is performed for each cell.

$$\frac{a_{ij}}{\sqrt{\sum_{i=1}^{m} a_{ij}^2}} \quad (7)$$

a_{ij}: Value of alternative i for criterion j

Step 2: Obtaining of the Weighted Normalize Matrix

The weighted normalized matrix is obtained with multiplying the normalized matrix by decision criteria's weights.

Step 3: Obtaining of the Positive and Negative Ideal Solution Values

Once the weighted normalized matrix is obtained, the maximal values of each column are determined considering problem structure. Namely if goal is maximization then maximum of each column are determined. These maximum values are the ideal solution values (v_j^+). Then minimum values for each column are obtained. These minimum values are the negative ideal solution values (v_j^-) . If the goal is minimization, the opposite of the obtained values is valid for analysis. Thus, ideal and negative ideal solution values are obtained.

Step 4: Obtaining of the Ideal and Non-Ideal Distance Values

The formulas used in the calculation of the positive and negative ideal distances are given below, respectively.

$$S_i^+ = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^+)^2}, \quad S_i^- = \sqrt{\sum_{j=1}^{n}(v_{ij} - v_j^-)^2} \quad (8)$$

Step 5: Calculating of the Ideal Solving Relative Proximity

In the calculating of the ideal solving relative proximity, the formula is used below.

$$C_i^* = \frac{s_i^-}{s_i^- + s_i^+} \quad (9)$$

2.4. MOORA Ratio Method

In the ratio system, the initial values of the alternatives are normalized on the basis of the criteria. Each alternative on the criteria basis is compared with a denominator (divisor) that represents all alternatives related to this criterion. The denominator contains the square root of the sum of the squares of values of each alternative takes in each criterion. The formula is given below:

x_{ij} : value of alternative i for criterion j; $i = 1, 2..m$; m represents number of the alternatives; $j = 1, 2..n$; n represents number of the criteria,

x_{ij}^* : normalized value of alternative i for criterion j; $i = 1, 2..m$; m represents number of alternatives ; $j = 1, 2..n$; n represents number of the criteria (Kracka, Brauers, and Zavadskas, 2010).

$$x_{ij}^* = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (10)$$

After the values of the alternatives based on the criteria have been normalized according to the formulation above. Normalized values are added in maximization and subtracted in minimization as stated in the following formula (Stanujkic, Magdalinovic, Stojanovic and Jovanovic 2012).

$$y_i^* = \sum_{j=1}^{g} x_{ij}^* - \sum_{j=g+1}^{n} x_{ij}^* \quad (11)$$

x_{ij}^* : normalized value of the alternative i for criterion j

$j = 1, 2..g$ states that criteria which are maximized

$j = g+1, g+2..n$ states that criteria which are minimized

$i = 1, 2...m$ states the alternatives

y_i^* : states the total ranking index of the alternative i where $y_i^* \in [-1, 1]$

The ordering of y_i^* will give the final state, so the best alternative that has the highest value of y_i^* while the worst alternative has the lowest value of y_i^* (Chakraborty 2011). In some cases, some criteria may be considered more important than others. In order to give more importance to these criteria, the criteria can be multiplied by the appropriate weights / significance coefficients (Brauers and Zavadskas, 2009). The following equation can be used when considering these significance coefficients;

$$y_j^* = \sum_{j=1}^{g} w_j x_{ij}^* - \sum_{j=g+1}^{n} w_j x_{ij}^* \qquad (12)$$

w_j states the weight of criteria j .

3. Findings

In the study, the obtained performance rankings of the metropolitan municipalities according to 3 different methods are shown in Table 2. Moreover, the overall trend of performance scores related to the methods is shown in Figure 2.

According to the results, Aydın Metropolitan Municipality, where the first established wastewater treatment plant in Turkey, is ranked in the first place in the first two methods and is ranked the second place in the third method. Konya and Ankara Metropolitan Municipalities located in the Central Anatolian Region are located in the upper ranks in the methods because of the high-water needs.

In the last rankings, the metropolitan municipalities are located in the Eastern and South Eastern Anatolian Regions, where the industry has not been developed sufficiently. Istanbul Metropolitan Municipality, which has the highest population, is in 4th place in one method and 9th and 10th in the other two methods, respectively. This can be considered as a success for the city where about 20% of the Turkish population lives. İzmir Metropolitan Municipality, which is 3rd biggest city in Turkey, is in the middle ranks.

Table 2. The obtained performance rankings of the metropolitan municipalities according to 3 different methods.

Metropolitan Municipality	ENTROPY-SAW	ENTROPY-MOORA	ENTROPY-TOPSİS
Adana	13	14	19
Ankara	2	3	7
Antalya	12	13	17
Aydın	1	1	2
Balıkesir	16	11	16
Bursa	19	21	22
Denizli	10	5	6
Diyarbakır	20	22	23
Erzurum	28	27	28
Eskişehir	6	8	8
Gaziantep	7	10	13
Hatay	26	24	26
Mersin	8	6	5
İstanbul	4	9	10
İzmir	11	19	18
Kayseri	14	20	20
Kocaeli	9	16	15
Konya	3	4	4
Malatya	22	25	24
Manisa	21	17	14
Kahramanmaraş	30	29	30
Mardin	29	30	29
Muğla	15	15	12
Ordu	17	7	3
Sakarya	25	26	25
Samsun	5	2	1
Tekirdağ	24	18	11
Trabzon	23	23	21
Şanlıurfa	27	28	27
Van	18	12	9

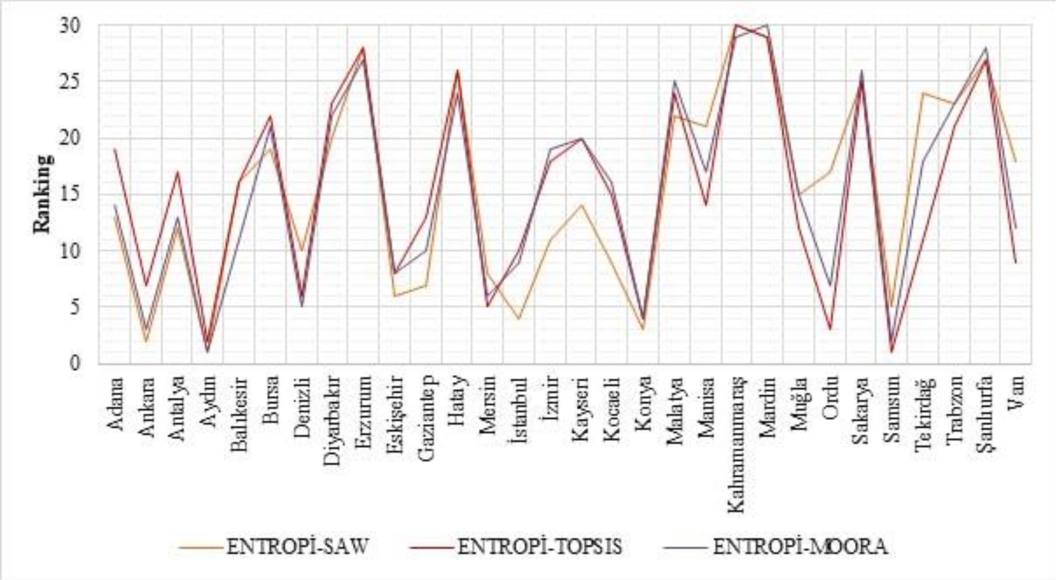

Figure 2. The overall trend of performance scores related to the methods.

4. Result and Discussion

As the performances of the metropolitan cities are examined, it can be seen that the cities such as Adana, Manisa, Bursa and Kocaeli, where the industry has developed rapidly, are located in the middle ranks. In case the development process of the industry is examined, it will be a realistic approach to predict that the water needs in these cities will increase. In this context, these cities need to improvement of the wastewater treatment performance.

In addition, since the wastewater treatment performance of coastal cities directly affects marine pollution, it can be said that precaution should be taken to increase the wastewater treatment performance in these cities. On the other hand, it is known that Mardin, Şanlıurfa and Kahramanmaraş metropolitan municipalities, which are located in the last ranks, have already projected wastewater treatment facilities.

In conclusion, it is known that, recycling of wastewater has become important due to the increasing population, developing industry and increasing water demand. In this context, in order to emphasize the importance of wastewater, conducted services related to this issue have been investigated for Turkey. This study can be extended for different countries, more criteria or alternatives. Moreover, different MCDM methods that have different structure and characteristic can be considered to support the results.

5. References

Alizadeh, S., Rad, M.M.S., Bazzazi, A.A. 2016. Alunite processing method selection using the AHP and TOPSIS approaches under fuzzy environment. International Journal of Mining Science and Technology, 26(6), 1017–1023.

Balkema, A.J., Preisig, H.A., Otterpohl, R., Lambert, F.J.D. 2002. Indicators for the sustainability assessment of wastewater treatment systems. Urban water, 4(2), 153–161.

Benedetti, L., Baets, B.D., Nopens, I., Vanrolleghem, P.A. 2010. Multi-criteria analysis of wastewater treatment plant design and control scenarios under uncertainty. Environmental modelling and software, 25(5), 616–621.

Blackwood, D.J., Ashley, R.M., Petrie, M., Oltean-Dumbrava, C. Jones, C. 2000. Making decisions for upgrading wastewater systems. In Proceedings of the Institution of Civil Engineers-Municipal Engineer, Thomas Telford Ltd, 171–180.

Bottero, M., Comino, E., Riggio, V. 2011. Application of the analytic hierarchy process and the analytic network process for the assessment of different wastewater treatment systems. Environmental Modelling and Software, 26(10), 1211–1224.

Brauers, W.K.M., Zavadskas, E.K. 2009. Robustness of the multi-objective MOORA method with a test for the facilities sector. Technological and Economic Development of Economy, 15(2), 352–375.

Chakraborty, S. 2011. Applications of the MOORA method for decision making in manufacturing environment. The International Journal of Advanced Manufacturing Technology, 54(9), 1155–1166.

Churchman, C.W., Ackoff, R.L. 1954. An approximate measure of value. Journal of the Operations Research Society of America, 2(2), 172–187.

Flores-Alsina, X., Rodriguez-Roda, I., Sin, G., Gearney, K.V. 2008. Multi-criteria evaluation of wastewater treatment plant control strategies under uncertainty. Water Research, 42(17), 4485–4497.

Hidalgo, D., Irusta, R, Martinez, L., Fatta, P., Papadopoulos, A. 2007. Development of a multi-function software decision support tool for the promotion of the safe reuse of treated urban wastewater. Desalination, 215(1), 90–103.

Hwang, C.L., Yoon, K. 2012. Multiple attribute decision making: methods and applications a state-of-the-art survey, Springer Science and Business Media, USA, 180-192.

Ishikawa, K., Kusuda, T. 1996. Urban Environmental with Evaluation on Cost, Benefit and Risk. Enviromental System Research, 24(1), 330–335.

Karagiannidis, A., Perkoulidis, G. 2009. A multi-criteria ranking of different technologies for the anaerobic digestion for energy recovery of the organic fraction of municipal solid wastes. Bioresource Technology, 100(8), 2355–2360.

Kim, Y., Chung, E.S., Jun, S.M., Kim, S.U. 2013. Prioritizing the best sites for treated wastewater instream use in an urban watershed using fuzzy TOPSIS. Resources, Conservation and Recycling, 73(1), 23–32.

Kracka, M., Brauers, W.K.M., Zavadskas, E.K. 2010. Buildings external walls and windows effective selection by applying multiple criteria method, Proceedings of Modern Building, Materials, Structures and Techniques The 10th International Conference, Vilnius, Lithuania, 436-442.

Ouyang, X., Guo, F., Shan, D., Yu, H., Wang, J. 2015. Development of the integrated fuzzy analytical hierarchy process with multidimensional scaling in selection of natural wastewater treatment alternatives. Ecological Engineering, 74, 438–447.

Ozcan, E. 2014. Turkiye'de Atıksu Yönetimi (Report No.13378), Kocaeli, Turkey, Tübitak MAM 25 pp.

Palme, U., Lundin, M., Tillman, A.M., Molander, S. 2005. Sustainable development indicators for wastewater systems–researchers and indicator users in a co-operative case study. Resources, Conservation and Recycling, 43(3), 293–311.

Ranade, V.V., Bhandari, V.M. 2014. Industrial Wastewater Treatment, Recycling and Reuse, Oxford, United Kingdom, Elsevier, 1-80 pp

Shabmardan, A., Zadeb, M.H. 2013. B An integrated approach for solving a MCDM problem, Combination of Entropy Fuzzy and F-PROMETHEE techniques. Journal of Industrial Engineering and Management, 6(4), 1124-1138.

Stanujkic, D., Magdalinovic, N., Stojanovic, S., Jovanovic, R. 2012. An objective multi-criteria approach to optimization using MOORA method and interval grey number. Informatica, 23(1),141–154.

TUIK 2014. Municipal Wastewater Statistics in Turkey. Retrieved from http://www.tuik.gov.tr/PreHaberBultenleri.do?id=24875.

Volcke, E.I.P., Gillot, S., Vanrolleghem, P.A. 2002. Multi-criteria evaluation of control strategies for wastewater treatment processes. IFAC Proceedings Volumes, 35(1), 417–422.

Wang, T.C., Lee, H.D. 2009. Developing a fuzzy TOPSIS approach based on subjective weights and objective weights. Expert Systems with Applications, 36(5), 8980–8985.

Wu, H.Y., Tzeng, G.H., Chen, Y.H. 2009. A fuzzy MCDM approach for evaluating banking performance based on Balanced Scorecard. Expert Systems with Applications, 36(6), 10135–10147.