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Research Article

A Comparative Analyze Based On EATWOS and OCRA Methods For Supplier Evaluation

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ABSTRACT

In the conditions of increasing competition, the methods of evaluating and selecting suppliers which are one of the most important part of the supply chains have gained importance for the companies. To evaluate the potential or current suppliers, applying quantitative analysis can be helpful for the company management. In this paper, efficiencies of suppliers are evaluated with EATWOS (Efficiency Analysis Technique With Output Satisficing) and OCRA (Operational Competitiveness RAting) methods. The ranking of the suppliers are determined based on their efficiency scores then the obtained results are compared.

Keywords: Supplier Evaluation, Efficiency, EATWOS, OCRA

Tedarikçi Değerlendirmesinde EATWOS ve OCRA Yöntemlerine Dayalı Karşılaştırmalı Bir Analiz

ÖZ

Artan rekabet koşullarında, tedarik zincirinin en önemli parçalarından biri olan tedarikçileri değerlendirme ve seçme yöntemleri şirketler için önem kazanmıştır. Potansiyel veya mevcut tedarikçileri değerlendirmek için, nicel analizlerin uygulanması şirket yönetimine yardımcı olabilir. Bu yazıda, tedarikçilerin verimliliği EATWOS ve OCRA yöntemleri ile değerlendirilmiştir. Tedarikçilerin sıralaması verimlilik puanlarına göre belirlenmiş ve elde edilen sonuçlar karşılaştırılmıştır.

Anahtar Kelimeler: Tedarikçi Değerlendirme, Etkinlik, EATWOS, OCRA

1. Introduction

Supplier evaluation is the process of assessing the potential or current suppliers by using quantitative analysis. It is also a process used to evaluate current suppliers in order to measure their performance in the aims of reducing cost and improving themselves. In the literature quantitative analysis are proposed to evaluate the suppliers. According to the results of the evaluation process the purchasing manager and company management can decide to establish long term relationships with existing suppliers or seek new ones. Besides, if these evaluation results are shared with the suppliers, they can also improve themselves by recognizing their current status. By this way, both companies and their suppliers can reduce costs and increase profitability. On the other hand, evaluation of supplier performance helps companies to restructure their supply network.

The subject of supplier evaluation and selection is an area that continues to attract attention in the literature and it has been studied extensively. In this evaluation process, quantitative techniques like Data Envelopment Analysis (DEA), mathematical programming, Analytic Hierarchy Process (AHP), Analytic Network Process (ANP), fuzzy set theory, Simple multi-attribute rating technique, Genetic algorithm and other integrated approaches are proposed. A detailed literature review about supplier evaluation can be found in the article of Ho et al. (2010). The novelty of this paper from others in the literature, EATWOS and OCRA methods are applied to supplier evaluation and the obtained results are compared.

The rest of this paper is organized as follows. After a brief introduction section, EATWOS method is introduced and its steps are summarized in the second section. In section three, OCRA method is explained. Section four presents the application. The last section concludes the paper, at the same time in this section suggestions for future studies are also given.

2. EATWOS Method

EATWOS method was firstly proposed by Peters and Zelewski (2006). It is an efficiency analysis method based on satisficing concept and supports the decision-making unit to lead to satisfactory solutions instead of optimum solutions (Peters and Zelewski, 2006). This method has been implemented in different fields to measure the efficiencies. For example it has been used in performance evaluation of vendors of a packaged drinking water manufacturer and distributer (Bansal et al., 2014), analyzing private pension companies in Turkey (Özbek, 2015a), measuring the efficiency of Turkish Red Crescent Society (Özbek, 2015b), analyzing the efficiency of five non-governmental organizations in Turkey (Özbek, 2015c), ranking the players of the Indian Premier League based on the statistics of 2013 season (Kumar et al., 2016) efficiency analysis of gold production companies by using financial statements of the companies between 2008 and 2015 (Özbek, 2016), efficiency analysis of a charity organization (Özbek, 2018).

In EATWOS method, decision makers have the opportunity of determining satisficing levels for outputs. In this paper, EATWOS method without consideration of satisficing levels is used. The steps of the EATWOS method without consideration of satisficing levels can be given as (Peters and Zelewski, 2006):

Step 1. In the first step, inputs and outputs are determined by the decision makers. Later, decision making units (DMUs) are clarified. Then, the output matrix $\underline{Y}$ and input matrix $\underline{X}$ are constructed by using the output quantities y_{ij} and input quantities x_{ik} for all DMUs.

$$\underline{Y} = \begin{bmatrix} y_{11} & y_{12} & \cdots & y_{1j} & \cdots & y_{1J} \\ y_{21} & y_{22} & \cdots & & \cdots & y_{2J} \\ \cdots & \cdots & & & & \cdots \\ y_{i1} & y_{i2} & \cdots & y_{ij} & \cdots & y_{iJ} \\ \cdots & \cdots & & & & \\ y_{I1} & y_{I2} & \cdots & y_{Ij} & \cdots & y_{IJ} \end{bmatrix} \quad y_{ij} \in R_{\geq 0} \quad \forall i = 1, \dots, I, \quad \forall j = 1, \dots, J \tag{1}$$

In this matrix, DMUs are placed on the rows and outputs are placed on the columns. Later, input matrix $\underline{X}$ is constructed and in this matrix, DMUs are placed on the rows and inputs are placed on the columns.

$$\underline{X} = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1k} & \cdots & x_{1K} \\ x_{21} & x_{22} & \cdots & & \cdots & x_{2K} \\ \cdots & \cdots & & & & \cdots \\ x_{i1} & x_{i2} & \cdots & x_{ik} & \cdots & x_{iK} \\ \cdots & \cdots & & & & \\ x_{I1} & x_{I2} & \cdots & x_{Ik} & \cdots & x_{IK} \end{bmatrix} x_{ik} \in R_{\geq 0} \quad \forall i = 1, \dots, I, \quad \forall k = 1, \dots, K \tag{2}$$

Step 2. After constructing input and output matrices, output quantities y_{ik} and input quantities x_{ik} are normalized by using Eq. (3) and Eq. (4) respectively.

The normalization formula for outputs:

$$\exists i,\ \exists j \qquad y_{ij} \neq 0 \quad r_{ij} = \frac{y_{ij}}{\sqrt{\sum_{i=1}^{I} y_{ij}^2}} \qquad \forall i = 1, \dots, I \quad \forall j = 1, \dots, J \tag{3}$$
$$\forall\ i = 1, \dots, I \quad \forall j = 1, \dots, J \qquad y_{ij} = 0 \qquad r_{ij} = 0$$

Here, y_{ij} is squared to avoid the denominator getting zero value.

The normalization formula for inputs:

$$\exists i,\ \exists k \qquad x_{ik} \neq 0 \quad s_{ik} = \frac{x_{ik}}{\sqrt{\sum_{i=1}^{I} x_{ik}^2}} \qquad \forall i = 1, \dots, I \quad \forall k = 1, \dots, K \tag{4}$$
$$\forall\ i = 1, \dots, I \quad \forall k = 1, \dots, K \qquad x_{ik} = 0 \qquad s_{ik} = 0$$

Later, normalized output matrix $\underline{R}$ and normalized input matrix $\underline{S}$ are constructed as given in Eq. (5) and Eq. (6) respectively.

$$\underline{R} = \begin{bmatrix} r_{11} & r_{12} & \cdots & r_{1j} & \cdots & r_{1J} \\ r_{21} & r_{22} & \cdots & & \cdots & r_{2J} \\ \cdots & \cdots & & & & \cdots \\ r_{i1} & r_{i2} & \cdots & r_{ij} & \cdots & r_{iJ} \\ \cdots & \cdots & & & & \\ r_{I1} & r_{I2} & \cdots & r_{Ij} & \cdots & r_{Ij} \end{bmatrix} \tag{5}$$

$$\underline{S} = \begin{bmatrix} s_{11} & s_{12} & \cdots & s_{1k} & \cdots & s_{1K} \\ s_{21} & s_{22} & \cdots & & \cdots & s_{2K} \\ \cdots & \cdots & & & & \cdots \\ s_{i1} & s_{i2} & \cdots & s_{ik} & \cdots & s_{iK} \\ \cdots & \cdots & & & & \\ s_{I1} & s_{I2} & \cdots & s_{Ik} & \cdots & s_{IK} \end{bmatrix} \quad (6)$$

Step 3. In the normalized output matrix $\underline{R}$ considering column vectors $\vec{r_j}$, maximum normalized output quantities r_j^* are determined for each output j with the help of Eq. (7).

$$r_j^* = \max_i\{\vec{r_j}\} \quad \forall j = 1, \dots, J \quad (7)$$

Later, in the normalized input matrix $\underline{S}$ considering column vectors $\vec{s_k}$, minimum normalized input quantities s_k^* are determined for each input k by using Eq. (8).

$$s_k^* = \min_i\{\vec{s_k}\} \quad \forall k = 1, \dots, K \quad (8)$$

Step 4. For the outputs, distance measures op_{ij} are determined with the help of Eq. (9) considering matrix $\underline{R}$ and the maximum normalized output quantities r_j^*. The distance measure op_{ij} is taken as output score.

$$op_{ij} = 1 - \left(r_j^* - r_{ij}\right) \quad \forall i = 1, \dots, I \quad \forall j = 1, \dots, J \quad (9)$$

Later, for the inputs distance measures ip_{ik} are determined via Eq. (10) considering matrix $\underline{S}$ and the minimum normalized input quantities s_k^*. The distance measure ip_{ik} is taken as input score.

$$ip_{ik} = 1 + s_{ik} - s_k^* \quad \forall i = 1, \dots, I \quad \forall k = 1, \dots, K \quad (10)$$

Step 5. Finally, efficiency scores for each DMUs are calculated by using Eq. (11).

$$E_i = \frac{\sum_{j=1}^{J} v_j * o_{pj}}{\sum_{k=1}^{K} w_k * i_{pk}} \quad \forall i = 1, \dots, I \quad (11)$$

Here, v_j shows the relative importance weight of outputs wheras w_k shows the relative importance weight of inputs. These importance weights can be determined by using AHP, entropy method, SWARA or MACBETH.

Low efficiency score E_i means lower efficiency relative to the other DMUs and reversely, a high efficiency score E_i means a high efficiency. At the end, DMUs are ranked according to their efficiency scores in descending order.

3. OCRA Method

The OCRA (**O**perational **C**ompetitiveness **RA**ting) method was firstly proposed by Parkan in 1994. It is a relative performance measurement method and based on a nonparametric model. OCRA method is very useful to compare different decision making units and analyze different sectors. Another important feature of OCRA method is its ability to monitor and compare the performances of decision units over time.

In the literature, OCRA method has been successfully applied to various areas. For instance it was used in measuring the service performance of a subway system (Parkan, 1996a), evaluating the operational competitiveness profile of the hotels (Parkan, 1996b), selecting process for a semiconductor manufacturer according to their operational benefits (Parkan and Wu, 1996), competitive analysis of food processing industry's manufacturing plants (Jayanthi et al., 1996; 1999), measuring the operational performance of the software development teams of a bank (Parkan et al., 1997), process selection in a manufacturing sector (Parkan and Wu, 1998), measurement of the investment bank's performance (Parkan and Wu , 1999a), analyzing the relative operational performance of manufacturing industries in Hong Kong between the years 1987 and 1993 (Parkan and Wu, 1999b), solving robot selection problem (Parkan and Wu, 1999c), process selection (Parkan and Wu, 2000), evaluating the public transport company's performance (Parkan, 2002), measuring the drugstores' relative performances (Parkan, 2003), analyzing the Hungarian food industry's performance (Tóth, 2005), comparison of the two hotels' operational performance (Parkan, 2005), obtaining technical efficiency scores of farms in Bulgaria (Bakucs et al., 2011), solving a gear material selection problem (Chatterjee and Chakraborty, 2012) selecting facility location (Chakraborty et al., 2013), decision-making in manufacturing applications (Chatterjee, 2013), selection of flexible manufacturing system (Chatterjee and Chakraborty, 2014), material selection in sugar industry (Darji and Rao, 2014), selecting the most suitable nonconventional machining process (Madić et al., 2015), measuring the performances of foreign-capital banks (Özbek, 2015d), evaluating the performance of Turkish public banks (Özbek, 2015e), measuring the performances of foreign-capital banks (Özbek, 2015f), evaluating the hotel alternatives (Tuş Işık and Aytaç Adalı, 2016).

The steps of the OCRA method can be given as (Parkan and Wu, 2000; Chatterjee and Chakraborty, 2012):

Step 1: Firstly inputs, outputs and decision making units (DMUs) are determined by the decision makers. Then, output matrix $\underline{Y}$ and input matrix $\underline{X}$ are constructed as seen in Eq. (1) and Eq. (2).

Step 2: Then unscaled input indices are calculated by using Eq. (12):

$$\overline{I}_i = \sum_{k=1}^{K} w_k \frac{\max(x_{ik}) - x_{ik}}{\min(x_{ik})} \qquad (i = 1,\ 2,\ \ldots,\ I \quad k = 1, 2,\ \ldots,\ K) \qquad (12)$$

Here K is the number of input and w_k is the weight of input k.

Step 3: In the third step, input indices are scaled via Eq. (13).

$$\overline{\overline{I}}_i = \overline{I}_i - \min(\overline{I}_i) \qquad (13)$$

Step 4: In the fourth step, unscaled output indices are calculated by using Eq. (14):

$$\overline{O}_i = \sum_{j=1}^{J} v_j \frac{x_{ij} - \min(x_{ij})}{\min(x_{ij})} \qquad (i = 1,\ 2,\ \ldots,\ I \quad j = 1,\ 2,\ \ldots.,\ J) \qquad (14)$$

Here J shows the number of outputs and v_j is the importance weight of output j. $\sum_{k=1}^{K} w_k + \sum_{j=1}^{J} v_j = 1$ equality must be ensured. In other words, the sum of the weights of inputs and outputs must equal to one.

Step 5: In the fifth step, output indices are scaled by using Eq. (15).

$$\bar{\bar{O}}_i = \bar{O}_i - \min(\bar{O}_i) \quad (15)$$

Step 6: Finally, the scaled efficiency indices for each DMUs are calculated via Eq. (16) and the DMU that has the lowest efficiency will take the value of zero.

$$E_i = (\bar{\bar{I}}_i + \bar{\bar{O}}_i) - \min(\bar{\bar{I}} + \bar{\bar{O}}) \quad i = 1,2,...,m \quad (16)$$

Alternatives are ranked according to their scaled efficiency indices in descending order.

4. Application

In this part, supplier evaluation problem of Talluri and Narasimhan (2003) is considered. The same problem is solved with EATWOS and OCRA methods and then the obtained results are compared. In this supplier evaluation problem, six suppliers will be evaluated. In the evaluation process price is considered as input whereas acceptance and on time deliveries are outputs. The data of these six suppliers are given on Table 1.

	Input	**Output**	
Suppliers	**Price ($/unit)**	**Acceptance (%)**	**On Time Deliveries (%)**
S_1	0.1958	98.8	95
S_2	0.1881	99.2	93
S_3	0.2204	100	100
S_4	0.2081	97.9	100
S_5	0.2118	97.7	97
S_6	0.2096	98.8	96

Table 1. Data of the suppliers

Firstly, suppliers are evaluated by using EATWOS method. According to this method, output and input quantities are normalized with the help of Eq. (3) and Eq. (4). These normalized values are given on Table 2.

	Input	**Output**	
Suppliers	**Price ($/unit)**	**Acceptance (%)**	**On Time Deliveries (%)**
S_1	0.3882	0.4099	0.4004
S_2	0.3729	0.4115	0.3920
S_3	0.4370	0.4149	0.4215
S_4	0.4126	0.4062	0.4215
S_5	0.4199	0.4053	0.4088
S_6	0.4156	0.4016	0.4046
	0.3729	**0.4149**	**0.4215**

Table 2. Normalized input and output values

After normalized input and output values are calculated, maximum normalized output quantities and minimum normalized input quantity are determined via Eq. (7) and Eq (8) respectively. These values can be seen at the last row of the Table 2.

Later distance measures for the outputs and inputs are calculated by using Eq. (9) and Eq. (10). These obtained values are summarized on Table 3.

	Input	Output	
Suppliers	**Price**	**Acceptance**	**On Time Deliveries**
S_1	1.0153	0.9950	0.9789
S_2	1.0000	0.9967	0.9705
S_3	1.0640	1	1
S_4	1.0397	0.9913	1
S_5	1.0470	0.9905	0.9874
S_6	1.0426	0.9867	0.9831
Weights	**1**	**0.5**	**0.5**

Table 3. Distance measures

Lastly, input and output distance measures are utilized to obtain an efficiency score for each decision making unit via Eq. (11) as seen in Table 4. Then suppliers are ranked according to these efficiency scores in descending order.

	Input
Suppliers	**Price**
S_1	0.9721
S_2	0.9836
S_3	0.9398
S_4	0.9577
S_5	0.9445
S_6	0.9447

Table 4. Efficiency scores of suppliers

According to the effciency scores of the suppliers, their ranking is obtained as $S_2 > S_1 > S_4 > S_6 > S_5 > S_3$. The same ranking is obtained with Talluri and Narasimhan (2003).

After the ranking of suppliers according to their efficiencies with EATWOS method is obtained, OCRA method is used to evaluate them. In OCRA method, unscaled input indices are determined with the help of Eq. (12) by considering the data on Table 1. In OCRA method the sum of the weights of inputs and outputs must equal to 1. So in the calculation, the weight of I_1 is taken as 0.5, and the weight of O_1 is s 0.25 and weight of O_2 is 0.25. The obtained values are given on Table 5.

Suppliers	**I_1**
S_1	0.0654
S_2	0.0859
S_3	0.0000
S_4	0.0327
S_5	0.0229
S_6	0.0287

Table 5. Unscaled input indices

Later, input indices are scaled with the help of Eq. (13) as seen in Table 6.

Suppliers	**I_i**
S_1	0.0654
S_2	0.0859
S_3	0.0000
S_4	0.0327
S_5	0.0229
S_6	0.0287

Table 6. Scaled input indices

Then, unscaled output indices are determined by using Eq. (14) and given in Table 7.

Suppliers	O_1	O_2	Total
S_1	0.0052	0.0054	0.0105
S_2	0.0062	0.0000	0.0062
S_3	0.0083	0.0188	0.0271
S_4	0.0028	0.0108	0.0217
S_5	0.0023	0.0108	0.0131
S_6	0.0000	0.0081	0.0081

Table 7. Unscaled output indices

Later, scaled output indices are calculated for outputs with the help of Eq. (15) as seen in Table 8.

Suppliers	O_i
S_1	0.0043
S_2	0.0000
S_3	0.0209
S_4	0.0155
S_5	0.0069
S_6	0.0019

Table 8. Scaled output indices

Finally, the scaled efficiency indices for each supplier are calculated by using Eq. (16).

Suppliers	P_i
S_1	0.0489
S_2	0.0650
S_3	0.0000
S_4	0.0273
S_5	0.0089
S_6	0.0097

Table 9. Scaled efficiency indices

Suppliers are ranked according to their scaled efficiency indices. Then, the ranking of the suppliers according to their efficiencies with OCRA method is obtained as $S_2 > S_1 > S_4 > S_6 > S_5 > S_3$. OCRA method obtained the same ranking with EATWOS method and Talluri and Narasimhan (2003).

5. Conclusion

Companies have to evaluate and select the appropriate suppliers for their supply chains in order to compete in today's dynamic and global markets. For this reason, evaluating the suppliers has an essential role for the companies. In this evaluation process various efficiency analysis can be used. In this paper, EATWOS and OCRA methods are proposed for this aim. The suppliers are firstly evaluated with EATWOS method. In the evaluation process input is determined as “price” and there are two outputs as “acceptance” and “on time deliveries”. Six current suppliers of the company are evaluated with the help of EATWOS method. The ranking of the suppliers according to their efficiencies with EATWOS method is obtained as S2 >S1 >S4 >S6 >S5 >S3. Later the suppliers are also evaluated with OCRA method and the same raking is obtained with EATWOS method. The results indicate that these two methods are suitable for supplier evaluation.

In future studies other efficiency analysis like DEA can be used to evaluate the suppliers and the results can be compared. And the weights of inputs and outputs used in OCRA and EATWOS method can be determined by AHP, MACBETH, SWARA and entropy method. Lastly, EATWOS and OCRA methods can be used to evaluate the efficiencies of different DMUs like branches of banks, schools, universities, companies that operate in the same sector etc..

References

Bakucs, Z., Fertő, I., Fogarasi, J., Tóth. J. & Latruffe, L. (2011). Assessment of the impact of EU accession upon farms' performance in the New Member States with special emphasis on the farm type (Rapport N° FACEPA Deliverable No. D 5.3 – February 2011). 46 p.

http://prodinra.inra.fr/record/266323

Bansal, A, Singh R. Kr., Issar, S. & Varkey, J. (2014). Evaluation of vendors ranking by EATWOS approach. Journal of Advances in Management Research, 11(3), 290-311.

Chatterjee, P. & Chakraborty, S. (2012). Material selection using preferential ranking methods. Material and Design, 35, 384-393.

Chatterjee, P. & Chakraborty, S. (2014). Flexible manufacturing system selection using preference ranking methods: A comparative study. International Journal of Industrial Engineering Computations, 5, 315–338.

Chatterjee, P. (2013). Applications of preference ranking-based methods for decision-making in manufacturing environment. PhD Thesis, Jadavpur University, Kolkata.

Darji, V.P. & Rao, R.V. (2014). Intelligent multi criteria decision making methods for material selection in sugar industry. Procedia Materials Science, 5, 2585 – 2594.

Ho, W., Xu, X. & Dey, P. K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. European Journal of Operational Research, 202, 16–24.

Jayanthi, S., Kocha, B. & Sinha, K.K. (1996). Competitive analysis of U.S food processing plants. The Retail Food Industry Center, Working Paper, 96-04.

Jayanthi, S., Kocha, B. & Sinha, K.K. (1999). Competitive analysis of manufacturing plants: an application to the US processed food industry. European Journal of Operational Research, 118 (2), 217–234.

Kumar, N., Singh, A., Verma, A. & Sonal T. (2016). Measuring efficiency of IPL players using EATWOS. International Journal of Advanced Production and Industrial Engineering, 1(2), 13-16.

Madić, M., Petković, D. & Radovanović, M. (2015). Selection of non-conventional machining processes using the OCRA method. Serbian Journal of Management, 10 (1), 61 – 73.

Özbek, A. (2015a). Analysis of private pension companies in Turkey by EATWOS. European Journal of Business and Management, 7(26), 31-43.

Özbek, A. (2015b). Efficiency analysis of the Turkish Red Crescent between 2012 and 2014. International Business Research, 7(9), 322-334.

Özbek, A. (2015c). Efficiency analysis of non-governmental organizations based in Turkey. International Business Research, 8(9), 95-104.

Özbek, A. (2015d). Operasyonel rekabet değerlendirmesi (OCRA) yöntemiyle mevduat bankalarinin etkinlik ölçümü. NWSA-Social Sciences, 10(3), 120-134.

Özbek, A. (2015e). Performance analysis of public banks in Turkey. International Journal of Business Management and Economic Research, 6(3), 178–186.

Özbek, A. (2015f). Efficiency analysis of foreign-capital banks in Turkey by OCRA and MOORA environment. Research Journal of Finance and Accounting, 6(13), 21–31.

Özbek, A. (2016). Efficiency analysis of gold mining companies through financial statements. International Journal of Academic Research in Business and Social Sciences, 6(10), 273-287.

Özbek, A. (2018). Efficiency analysis in charity organizations by multiple criteria decision making methods, Anadolu University Journal of Social Sciences, 18(2), 99-113.

Parkan, C. & Wu M.L. (1996). Selection of a manufacturing process with multiple benefit attributes. International Conference on Engineering and Technology Management. Managing Virtual Enterprises: A Convergence of Communications, Computing, and Energy Technologies. IEMC 96 Proceeding Book, pp. 447-452.

Parkan, C. & Wu, M.L. (1998). Process selection with multiple objective and subjective attributes. Production Planning & Control, 9(2), 189–200.

Parkan, C. & Wu, M.L. (1999a). Measurement of the performance of an investment bank using the operational competitiveness rating procedure. Omega, 27(2), 201-217.

Parkan, C. & Wu, M.L. (1999b). Measuring the performance of operations of Hong Kong's manufacturing industries. European Journal of Operational Research, 118(2), 235-258.

Parkan, C. & Wu, M.L. (1999c). Decision-making and performance measurement models with applications to robot selection. Computers & Industrial Engineering, 36(3), 503–523.

Parkan, C. & Wu, M.L. (2000). Comparison of three modern multicriteria decision-making tools. International Journal of Systems Science, 31(4), 497-517.

Parkan, C. (1994). Operational competitiveness ratings of production units. Managerial and Decision Economics, 15(3), 201-221.

Parkan, C. (1996a). Performance measurement for a subway system in Hong Kong. The Georgia Productivity Workshop II, Athens, GA.

Parkan, C. (1996b). Measuring the performance of hotel operations. Socio-Economic Planning Sciences, 30(4), 257–292.

Parkan, C. (2002). Measuring the operational performance of public transit company. International Journal of Operations & Production Management, 22(6), 693-720.

Parkan, C. (2003). Measuring the effect of a new point of sale system on the performance of drugstore operations. Computers & Operations Research, 30(4), 729-744.

Parkan, C. (2005). Benchmarking operational performance: the case of two hotels. International Journal of Productivity and Performance Management, 54(8), 679 – 696.

Parkan, C., Lam, K. & Hang, G. (1997). Operational competitiveness analysis on software development. The Journal of the Operational Research Society, 48(9), 892-905.

Peters, M. L. and Zelewski, S., (2006). Efficiency analysis under consideration of satisficing levels for output quantities. In Proceedings of the 17th Annual Conference of the Production and Operations Management Society, 28.04-01.05.2006 in Boston, pp.2-18.

Talluri, S. & Narasimhan R. (2003). Vendor evaluation with performance variability: A max–min approach. European Journal of Operational Research, 146, 543–552.

Tóth. J. (2005). Működési versenyképesség és hajtóerői a hazai húsiparban (Operational competitiveness and its driving forces in the Hungarian meat industry). Közgazdasági Szemle, LII. évf.. július–augusztus, 743-762.

Tuş Işık, A. & Aytaç Adalı, E. (2016). A new integrated decision making approach based on SWARA and OCRA methods for the hotel selection problem. International Journal of Advanced Operations Management, 8 (2), 140-151.