(REFEREED RESEARCH)

MACBETH BASED TAGUCHI LOSS FUNCTIONS APPROACH FOR GREEN SUPPLIER SELECTION: A CASE STUDY IN TEXTILE INDUSTRY

YEŞİL TEDARİKÇİ SEÇİMİ İÇİN MACBETH TABANLI TAGUCHİ KAYIP FONKSİYONLARI YAKLAŞIMI: TEKSTİL ENDÜSTRİSİNDE BİR UYGULAMA

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ABSTRACT

Due to the increasing concern towards environmental protection, companies have started to adapt environmentalist approaches with the aim of being perceived as green. However, this might not be enough in performing in a supply chain thus working with green partners is mandatory. Since suppliers have important effects on the performance of supply chains, it becomes more important to evaluate potential suppliers by considering environmental factors. This study proposes a novel integrated approach consisting of MACBETH and Taguchi loss functions for green supplier selection problem. The proposed approach determines the weights of criteria by using MACBETH in the first stage. These weights are used in Taguchi loss functions for ranking and selecting the best suppliers. A real case study from textile industry is presented to illustrate the applicability of the proposed methodology. Moreover, the impacts of the changes on criteria weights have been investigated through sensitivity analysis.

Keywords: Green supplier selection, MACBETH, Taguchi loss functions, Sensitivity analysis

ÖZET

Çevreyi koruma bilincinin artması sebebiyle, firmalar yeşil olarak algılanmak amacıyla çevreci yaklaşımları benimsemeye başlamışlardır. Bunun yanı sıra tedarik zincirinde bu yaklaşım yeterli olmayabilir ve yeşil tedarikçilerle işbirliği yapmak zorunlu hale gelebilir. Tedarikçiler, tedarik zincirlerinin performansı üzerinde önemli etkiye sahip olduklarından, çevresel faktörleri göz önüne alarak potansiyel tedarikçilerin değerlendirilmesi daha da önem kazanmaktadır. Bu çalışma, yeşil tedarikçi seçimi problemi için MACBETH ve Taguchi kayıp fonksiyonlarından oluşan yeni bütünleşik bir yaklaşım önermektedir. Önerilen yaklaşımın ilk aşamasında kriterlerin ağırlıkları MACBETH yöntemiyle belirlenmektedir. Bu ağırlık değerleri, Taguchi kayıp fonksiyonlarında en iyi tedarikçilerin sıralanması ve seçiminde kullanılmaktadır. Önerilen yöntemin uygulanabilirliği tekstil endüstrisinde bir vaka çalışması ile sunulmuştur. Ayrıca kriter ağırlıklarındaki değişimlerin yarattığı etki duyarlılık analizi ile araştırılmıştır.

Anahtar Kelimeler: Yeşil tedarikçi seçimi, MACBETH, Taguchi kayıp fonksiyonları, Duyarlılık analizi

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1. INTRODUCTION

Intensifying deterioration of the environment, increasing levels of pollution, overflowing waste sites and diminishing raw material resources [1], have led the green supply chain management (GSCM) become an important research area. Since 1990s, with the increasing concern towards environmental protection and pressure of consumers, governments have introduced new laws and regulations in order to control the activities of companies on environment. The first step in supply chain management is supplier selection decisions. Nowadays, companies have preferred to maintain long-term relationships with suppliers and used fewer but more reliable suppliers [2]. Considering the increase in the awareness of environment, companies tend to work with green suppliers who use recycling materials, undertake of minimizing carbon emissions, be environment-friendly as well as provide good products or services on time with shorter lead time. The multi-criteria nature of green supplier selection problem has stimulated the use of different multi criteria decision making (MCDM) techniques in literature. The interested reader can refer to Govindan *et al.* [3] who have presented a literature review focusing on MCDM approaches for green supplier evaluation and selection. For addressing the solution of green supplier selection problem, researchers have started to prefer integrated approaches consisting of different MCDM methods in recent years [4, 5, 6, 7, 8, 9, 10, 11, 12, 13].

In this paper, a novel integrated approach is proposed for addressing the solution of green supplier selection problem of a textile company. As the company has been through the process of new product development, the goal is to find appropriate green suppliers for woven labels. The proposed integrated approach consists of Measuring Attractiveness by a Categorical Based Evaluation Technique (MACBETH) and Taguchi loss functions. First, the relative weights of green supplier selection criteria are determined using MACBETH. Then, Taguchi loss functions are employed in order to calculate the loss values associated with each alternative supplier. Finally, the overall weighted Taguchi loss value of each alternative supplier is calculated.

To the best of authors' knowledge, this study is the first in which MACBETH and Taguchi loss functions are used in such a novel way. The literature review shows that Analytical Hierarchical Process (AHP) has been widely used in most of the integrated approaches [4, 6, 8, 9, 10, 11, 12]. MACBETH has the advantage of taking into account the customers' preferences from qualitative point of view. Due to pair-wise comparison of performance between two alternatives, it can provide accurate ranking of the suppliers and guide the decision makers to choose the best one [14]. Different applications of MACBETH can be found in literature such as reverse logistics [15], healthcare systems [16], wetlands [17] and sorting strategic products [18]. The other element of the proposed approach is the loss functions which have been proposed by Taguchi [19]. In recent years, Taguchi loss functions have been widely used as a MCDM method [20, 21, 22, 23, 24, 25]. In Taguchi loss functions, preferences can be expressed by defining target values, ranges and specification limits for tangible and intangible criteria. The main contribution of this paper is to combine the strong sides of these two methods and present a systematic decision making approach for a real case.

The rest of the paper is organized as follows. The following section presents a literature review on green supplier selection problem. In section three, the proposed integrated approach is explained in details. Section four illustrates an example on a real green supplier selection problem to validate the proposed integrated approach. Moreover, the impacts of the changes on criteria weights have been investigated through sensitivity analysis. The conclusion is given in section five with future research directions and limitation of this study.

2. LITERATURE REVIEW

In recent years, the green supplier selection problem has gained the attention of researchers. This section analyses the current literature between years 2007-2016. Table 1 summarizes the previous researches on green supplier selection problem in terms of methodology and application area in ascending order of the publication year.

Table 1. Summary of previous researches on green supplier selection problem

Authors	**Application area**	**Methodology**
Lu *et al*. [27]	Electronics industry	AHP
Yang and Wu [41]	Home appliances manufacturing	Grey entropy synthetic evaluation model
Bala *et al*. [42]	University administration	Cross case analysis
Yan [12]	Electronics industry	AHP and GA
Tuzkaya *et al.* [35]	Manufacturing industry	Fuzzy ANP and PROMETHEE
Lee et al. [28]	High-tech electronics industry	Delphi and fuzzy extended AHP
Hsu and Hu [33]	Electronics industry	ANP
Li and Zhao [8]	Vehicle components manufacturing	Grey correlational analysis and AHP
Thongchattu and Siripokapirom [10]	N/A	AHP and ANN
Hong-jun and Bin [43]	Manufacturing industry	Factor analysis
Awasthi *et al.* [39]	Logistics	Fuzzy TOPSIS
Feyzioğlu and Büyüközkan [44]	Home appliances manufacturing	Choquet integral
Kuo *et al*. [7]	Manufacturing+industry	ANN and DEA
Wen and Chi [11]	N/A	DEA-AHP and ANP
Chiou *et al*. [45]	A questionnaire in 8 different industries	Confirmatory factory analysis
Yeh and Chuang [46]	Electronics industry	Multi-objective genetic algorithms
Büyüközkan and Çifçi [31]	Automobile manufacturing	Fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS
Ertay *et al*. [27]	Renewable energy	MACBETH and fuzzy AHP
Shen *et al*. [40]	Automobile manufacturing	Fuzzy TOPSIS
Kannan *et al*. [6]	Automobile manufacturing	Fuzzy AHP, fuzzy TOPSIS and MOLP
Bakeshlou *et al*. [30]	N/A	Fuzzy ANP, fuzzy DEMATEL and fuzzy MOLP
Zhao and Guo [47]	Thermal power equipment	F-entropy and TOPSIS
Dobos and Vörösmarty [48]	N/A	DEA and composite indicators
Kannan *et al*. [49]	Electronics industry	Fuzzy TOPSIS
Akman [26]	Automobile manufacturing	Fuzzy c-means clustering, AHP and VIKOR
Hashemi *et al*. [32]	Automobile manufacturing	ANP and GRA
Kannan *et al*. [50]	Plastic manufacturing	Fuzzy axiomatic design
Azadnia *et al*. [4]	Food industry	Rule based weighted fuzzy method, fuzzy AHP and MOMP
Kuo *et al*. [34]	Electronics industry	DEMATEL, ANP and VIKOR
Rostamzadeh *et al*. [38]	Laptop manufacturing	Fuzzy VIKOR
Sivakumar *et al*. [25]	Mining industry	AHP and Taguchi loss functions
Awasthi and Kannan [36]	Automobile manufacturing	Fuzzy VIKOR
Banaeian *et al*. [37]	Agri-food industry	Fuzzy TOPSIS, fuzzy VIKOR and fuzzy GRA
Keshavarz Ghorabaee *et al*. [51]	N/A	Fuzzy WASPAS
Yazdani *et al*. [13]	Automobile manufacturing	QFD and SWARA
Rezaei *et al*. [52]	Edible oil industry	The best worst method
Luthra *et al*. [9]	Automobile manufacturing	AHP and VIKOR

Integration of MCDM methods provides different approaches with particular functionalities and characteristics [13]. Therefore, in last years the number of integrated approaches has shown a tremendous increase. One of the most widely used methods is AHP [6, 8, 9, 10, 11, 12, 25, 26, 27, 28, 29]. In order to consider direct and indirect relationships among criteria, Analytic Network Process (ANP) has also been applied in most of the studies [11, 30, 31, 32, 33, 34, 35]. Recently, researchers have preferred different MCDM approaches such as VIseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR) [9, 26, 34, 36, 37, 38], Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) [6, 31, 37, 39, 40], The Decision Making Trial and Evaluation Laboratory (DEMATEL) [30, 31, 34] in green supplier selection problems. However, Ertay *et al.* [27] Sivakumar *et al.* [25] are the first ones who have utilized MACBETH and Taguchi loss functions in their studies for green supplier selection.

To fill this gap, these two methods have been integrated for addressing the solution in this paper. The details of the proposed approach are given in the next section.

3. MATERIALS AND METHOD

3.1. The proposed approach

The proposed approach integrates MACBETH and Taguchi loss functions methods and consists of two stages. In the first stage, MACBETH has been used to obtain the weights of criteria. In the following stage, Taguchi loss functions method has been utilized for ranking the suppliers and determining the best supplier.

The main steps of the proposed approach are presented in Figure 1.

3.1.1. MACBETH

MACBETH is a MCDM method based on multi attribute utility theory introduced by Bana e Costa, in cooperation with Vansnick and De Corte [27, 53, 54]. Asking for simply qualitative judgments of the decision makers and then transforming them into numerical scores makes it easy to grasp and apply for different problems in various fields [55]. This method is also supported by a decision support software called M-MACBETH with the intention to ease the overall evaluation process [56].

3.1.2. Taguchi loss functions

Dr. Genichi Taguchi has developed a set of methodologies for applying statistics to increase process and product quality [21]. Till the recent studies, Taguchi philosophy has been accepted widely as an effective approach merely for quality engineering and design of experiment. In the last decades, Taguchi loss functions have been used as a MCDM approach [20, 21, 22, 23, 24, 25, 57]. Taguchi loss functions are categorized mainly into three groups as nominal is the best, lower is better and higher is better and the formulations and graphs related to functions are given in Figure 2, Figure 3, Figure 4 and Equation (1), Equation (2), Equation (3), respectively.

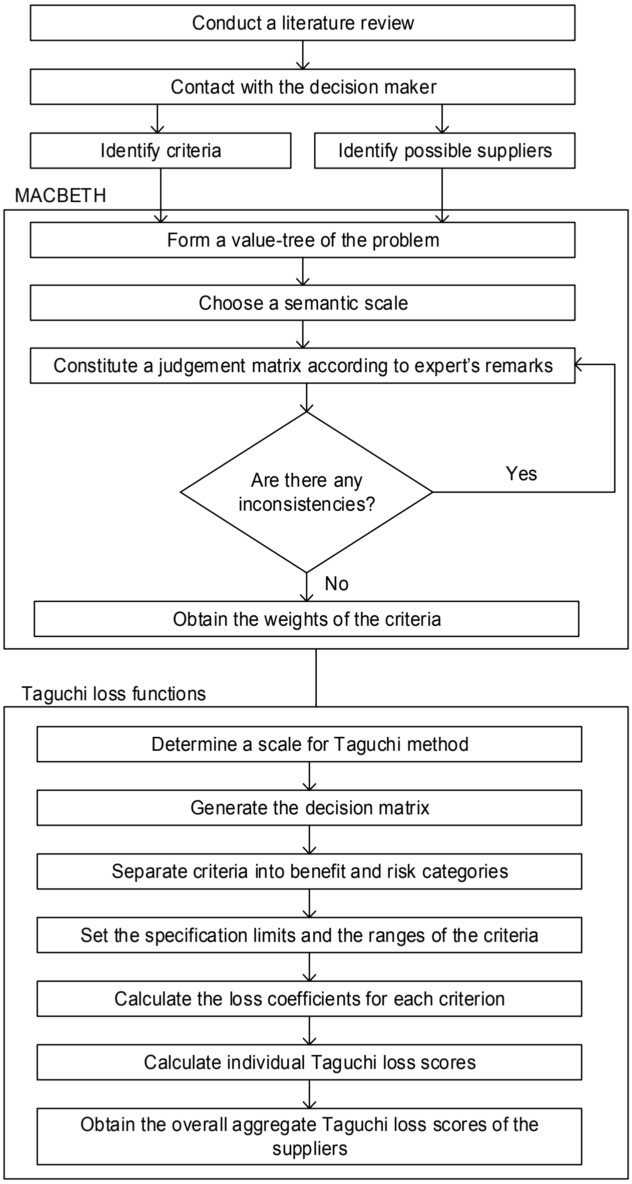

Figure 1. The proposed methodology

$$L(y) = k(y - m)^2 \tag{1}$$

where $L(y)$ is the loss associated with a particular quality character y , m is the specification goal, k is the loss coefficient, USL and LSL are the upper and lower specification limits. These notations are also valid for one-sided loss functions.

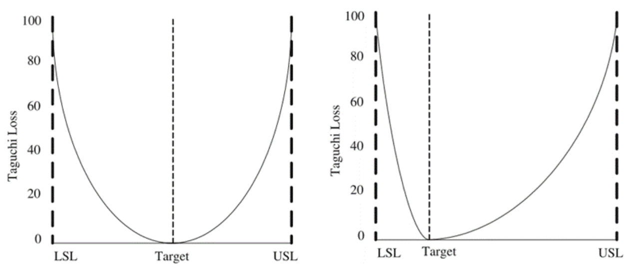

Figure 2. Nominal is the best loss function

$$L(y) = k \times y^2 \quad (2)$$

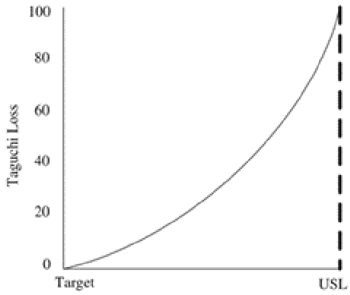

Figure 3. Lower is better loss function

$$L(y) = \frac{k}{y^2} \quad (3)$$

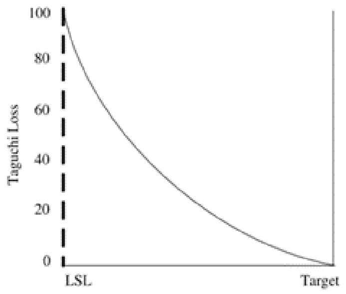

Figure 4. Higher is better loss function

4. RESULTS AND DISCUSSION

4.1. A case study

This study mainly focuses on the green supplier selection problem of a textile company located in Turkey that works with different woven labels' suppliers. Within this scope, four possible suppliers have been determined by the expert. As a result of increasing consciousness of environmental issues and being under pressure from customers' demand, the company tends to incorporate environmental criteria into supplier selection process. Therefore, the criteria shown in Table 3, have been determined considering green terms based on expert's remarks and findings of the literature review.

To obtain the weights of criteria, M-MACBETH decision support software has been used.

Once the structure of the problem has come out, the pairwise comparisons have been performed using a semantic scale based on expert's remarks. When establishing the judgment matrix, performance levels of the criteria are arranged according to descending order of their importance from left to right and top to bottom. The judgment matrix is shown in Table 4.

Table 3. The criteria used in this study

Criteria	**Explanation**
C1 - Quality	The degree of matching company's requirements of ordered products or raw materials, having lower rejection rate, providing quality certificates and awards.
C2 - Delivery time	The time between order initiated to product delivery, ability to react company's orders on time, to comply the due date and the schedule.
C3 - Production capacity	The amount of product that the supplier is able to produce within a unit of time.
C4 - Price	Appropriateness of the product price to the market price without compromising the quality.
C5 - Service level	The overall performance of the supplier in terms of reliance, responsiveness and satisfaction, compliance with the prespecified order of quantities, the degree of ability to change the orders when needed.
C6 - Management and organization	Having a modern vision and foresight about the market, strategic plans and the interests of the employees and stakeholders, management capability, willingness to information sharing.
C7 - Environmental competencies	Having environment-related certificate such as Oeko-tex, striving for continuous decrease in negative impact to the environment.

Table 4. Pairwise comparison of criteria

	C1	**C7**	**C6**	**C5**	**C4**	**C3**	**C2**
C1	no	weak	moderate	moderate	strong	very strong	very strong
C7	-	no	weak	moderate	moderate	very strong	very strong
C6	-	-	no	very weak	weak	strong	very strong
C5	-	-	-	no	very weak	moderate	strong
C4	-	-	-	-	no	weak	moderate
C3	-	-	-	-	-	no	very weak
C2	-	-	-	-	-	-	no

As shown in Table 4, quality criterion has slightly more preference level than environmental competencies criterion. But there is a strong divergence between the same criterion and delivery time criterion in terms of importance level.

In the last step of MACBETH approach, the weights of the criteria are determined based on pairwise comparison values by using linear programming model. The weights of criteria obtained by using M-MACBETH decision support software are shown in Table 5.

Table 5. The weights of supplier selection criteria

Criterion	Weight
C1 - Quality	0.2727
C7 - Environmental competencies	0.2273
C6 - Management and organization	0.1818
C5 - Service level	0.1477
C4 - Price	0.1136
C3 - Production capacity	0.0455
C2 - Delivery time	0.0114

It can be seen that quality criterion is the most important criterion with the weight of 0.2727, followed by environmental competencies and management and organization criteria that has 0.2273 and 0.1818, respectively.

In the next stage, the possible four suppliers have been evaluated and ranked by using Taguchi loss functions. The method starts with generating the decision matrix, which shows the evaluation of the suppliers based on the related criteria. While the decision matrix is being constituted according to decision maker's remarks, 0-100 scale is used to score the suppliers in order to apply more sensitivity to decision making process. The decision matrix is shown in Table 6.

The categories including benefit and risk have been determined in order to obtain ranges and specification limits. Regarding the quality criterion, as the highest grade shows the better quality, zero loss is occurred when 100 points is gained. Since the higher is better, this criterion is in benefit category. To calculate the specification limit of the related criterion, decision maker has indicated that the suppliers, which are above the 85 points limit, are appropriate for the assessment. Thus, any supplier that gets 85 points for the quality criterion will get 100% loss. Similar to quality criterion, delivery time, production capacity, service level, management and organization, environmental competencies criteria have been counted in benefit category and according to expert's remarks, the specification limit of each criterion has been determined as 75, 60, 90, 80 and 70, respectively. The price criterion has been assumed in risk (cost) category in order to minimize purchasing costs. Decision maker has stated that 90 points is the specification limit for the related criterion. Therefore, any supplier who gets 90 points for the price criterion, will get 100% loss.

The next step includes calculating the value of loss coefficient (k) for each criterion by using Equation (2) or Equation (3) with respect to benefit or risk categories. For example, the loss coefficient for quality criterion which is in benefit category, is calculated as follows,

$$k_1 = 100 \times (0.85)^2 = 72.25 \tag{4}$$

Regarding the price criterion, which is in risk (cost) category, the loss coefficient for this criterion is calculated via Equation (2). Thus,

$$k_4 = \frac{100}{(0.90)^2} = 123.46 \tag{5}$$

Table 7 shows the desired value, range of the allowable deviation, the specification limits, the loss coefficients as well as the weights that is calculated in the previous step by using MACBETH for each criterion.

Once Table 7 is obtained with calculated loss coefficient values, the individual Taguchi loss scores are calculated depending on supplier performance and the loss coefficients by using Equation (2) or Equation (3). The Taguchi loss score of supplier A for quality criterion is calculated as shown in Equation (6).

$$L(y_{1A}) = \frac{72.25}{(0.96)^2} = 78.40 \tag{6}$$

Regarding the price criterion, which is in risk (cost) category, the Taguchi loss score of supplier A is calculated via Equation (2) as given in Equation (7).

$$L(y_{4A}) = 123.46 \times (0.84)^2 = 87.11 \tag{7}$$

In the last step, individual Taguchi loss scores of the suppliers are multiplied by the weights of criteria that have been obtained by using MACBETH method. As a result, the overall aggregate Taguchi loss scores of the suppliers are given in Table 8.

Table 8 shows that supplier A has the minimum Taguchi loss score (75.53) stating that it is the most appropriate supplier for woven labels. Supplier D has been ranked as the second proper supplier followed by suppliers C and B, respectively.

Table 6. The decision matrix

Supplier	C1	C2	C3	C4	C5	C6	C7
	Max	Max	Max	Min	Max	Max	Max
A	96	89	78	84	95	92	90
B	91	92	83	87	93	87	78
C	94	87	74	79	96	85	85
D	93	84	68	82	93	90	92

Table 7. Specification limits of supplier selection criteria

Criteria	The weights of criteria	Desired value (%)	Range (%)	Specification limit (%)	Loss coefficient (k)
C1 - Quality	0.2727	100	85-100	85	72.25
C2 - Delivery time	0.0114	100	75-100	75	56.25
C3 - Production capacity	0.0455	100	60-100	60	36
C4 - Price	0.1136	0	0-90	90	123.46
C5 - Service level	0.1477	100	90-100	90	81
C6 - Management and	0.1818	100	80-100	80	64
C7 - Environmental competencies	0.2273	100	70-100	70	49

Table 8. Overall results of the suppliers

	Individual loss score of each supplier under each criterion							Total loss score
Supplier	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	
A	78.40	71.01	59.17	87.11	89.75	75.61	60.49	75.53
B	87.25	66.46	52.26	93.45	93.65	84.56	80.54	85.05
C	81.77	74.32	65.74	77.05	87.89	88.58	67.82	79.39
D	83.54	79.72	77.85	83.01	93.65	79.01	57.89	78.02
The weights of criteria	0.2727	0.0114	0.0455	0.1136	0.1477	0.1818	0.2273	

4.2. Sensitivity analysis

Figure 5 presents the effects of changes in the most important three criteria' weights on the overall scores of alternatives. Each alternative's line in the graph shows the variation of the alternative's overall score when the criterion weight changes from 0 to 100 %.

The vertical line represents the current weight of the criterion. While changing the weight of delivery time from 0 to 100 %, the overall scores of D and B decrease and that of A and C increases (see Figure 5(a)). For environmental competencies, when the weight increases, the overall scores of A and D increase while those of B and C decrease (Figure 5 (b)). Figure 5 (c) shows that when the weight of management and organization criterion changes, the overall scores of all alternatives increase except supplier C.

Sensitivity analysis demonstrates the possible variations of the preference level of the most important three criteria regarding criteria weights. As a result of the analysis, it can be stated that supplier A has additive dominance upon other suppliers In addition, in some cases with different criteria weights, supplier D obtains better preference level than supplier C. The overall scores of the alternatives D and C are slightly sensitive to the variation of criteria weights and the information level. Therefore, the decision to cooperate with two suppliers might be reanalyzed if any changes of prior knowledge occurs.

5. CONCLUSIONS

As the depletion of the resources has reached its limits and the consciousness about environment has increased day by day, this study is concerned with the application of environmental consideration into supplier selection process. Within this scope, an integrated approach including MACBETH and Taguchi loss functions methods is proposed to solve the green supplier selection problem of a textile company. Up to our knowledge, this study is the first one integrating MACBETH and Taguchi loss functions in a novel way. In the first stage, the weights of criteria have been determined by using MACBETH. In the following stage, the weights of criteria have been incorporated into Taguchi loss functions method as an input to evaluate the most suitable suppliers. Moreover, sensitivity analysis has been carried out to analyze the results in detail. This study deals with a deterministic decision making problem in which all data are assumed to be known. This might be the limitation of the study since in some problems all data can not be known exactly. Therefore, in order to capture the uncertainties, fuzzy logic might be utilized in the proposed approach.

Further research might be investigating the integrity of other MCDM approaches with Taguchi loss functions. Another research direction might be to develop a decision support system where appropriate suppliers and order sizes can be determined in succession.

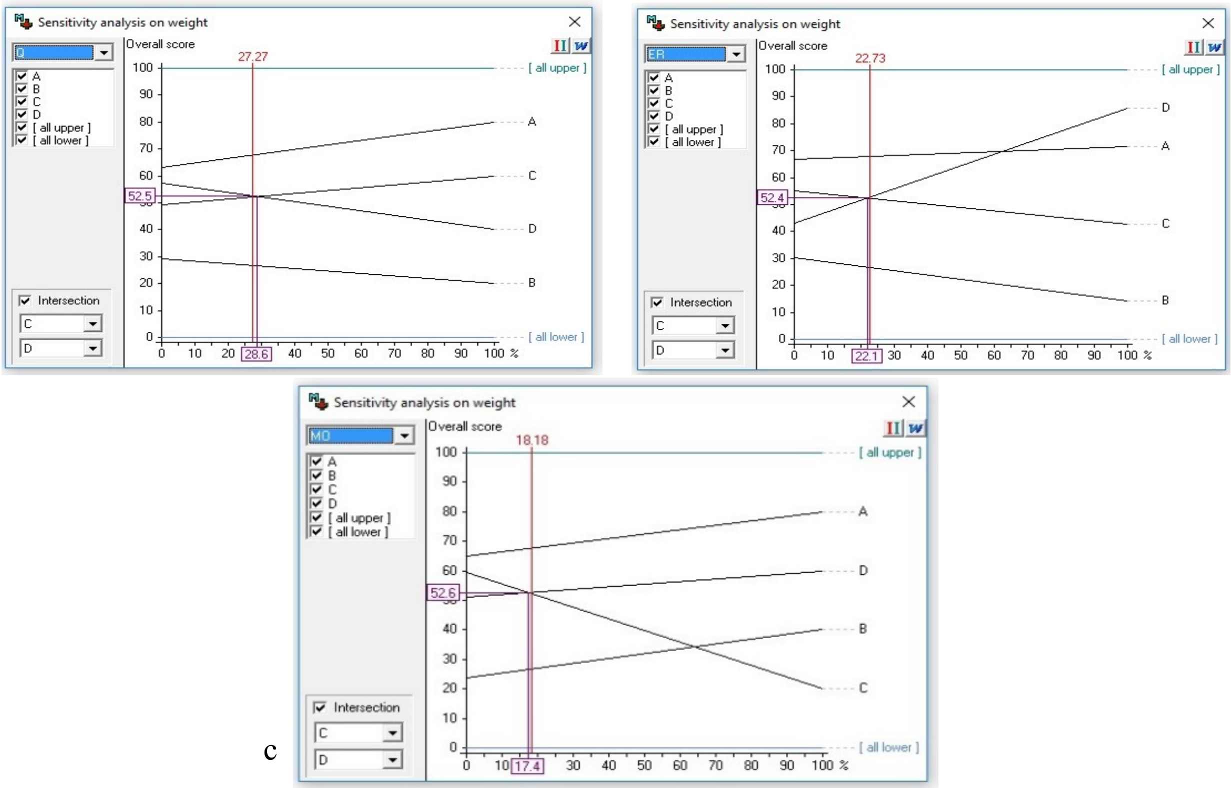

Figure 5. Sensitivity analysis for the most important three criteria (a) quality criterion (b) environmental competencies criterion (c) management and organization criterion

REFERENCES

1. Srivastava S.K., 2007, "Green supply-chain management: A state-of-the-art literature review", International Journal of Management Reviews, 9(1): 53-80.
2. Ho W., Xu X. and Dey P.K., 2010, "Multi-criteria decision making approaches for supplier evaluation and selection: a literature review", European Journal of Operational Research, 202(1): 16-24.
3. Govindan K., Sivakumar R., Sarkis J. and Murugesan P., 2015, "Multi criteria decision making approaches for green supplier evaluation and selection: a literature review", Journal of Cleaner Production, 98: 66-83.
4. Azadnia A.H., Saman M.Z.M. and Wong K.Y., 2015, "Sustainable supplier selection and order lot-sizing: an integrated multi-objective decision-making process", International Journal of Production Research, 53(2): 383-408.
5. Chen C.C., Tseng M.L., Lin Y.H. and Lin Z.S., 2010, "Implementation of green supply chain management in uncertainty" In: IEEE International Conference on IEEM, Dec. 7-10, pp. 260-264.
6. Kannan D., Khodaverdi R., Olfat L., Jafarian A. and Diabat A., 2013, "Integrated fuzzy multi criteria decision making method and multi-objective programming approach for supplier selection and order allocation in a green supply chain", Journal of Cleaner Production, 47: 355-367.
7. Kuo R.J., Wang Y.C. and Tien F.C., 2010, "Integration of artificial neural network and MADA methods for green supplier selection", Journal of Cleaner Production, 18(12): 1161-1170.
8. Li X. and Zhao C., 2009, "Selection of suppliers of vehicle components based on green supply chain", In: IEEE International Conference on IE&EM, 21-23-Oct, pp. 1588-1591.
9. Luthra S., Govindan K., Kannan D., Mangla S.K. and Garg C.P., 2016, "An integrated framework for sustainable supplier selection and evaluation in supply chains", Journal of Cleaner Production, 140(3): 1686-1698.
10. Thongchattu C and Siripokapirom S (2010). Green supplier selection consensus by neural network. In: International Conference on ICMEE, IEEE 1-3 Aug, pp. 313-316.
11. Wen U.P. and Chi J.M., 2010, "Developing green supplier selection procedure: a DEA approach", In: IEEE International Conference on IE&EM, 29-31 Oct, 79-74.
12. Yan G., 2009, "Research on green suppliers' evaluation based on AHP & genetic algorithm", In: IEEE International Conference on SPS, 15-17 May, pp. 615-619
13. Yazdani M., Zolfani S.H. and Zavadskas E.K., 2016, "New integration of MCDM methods and QFD in the selection of green suppliers", Journal of Business Economics and Management, 17(6): 1097-1113.
14. Karande P. and Chakraborty S., 2013, "Using MACBETH method for supplier selection in manufacturing environment", International Journal of Industrial Engineering Computations, 4(2): 259-279.
15. Dhouib D., 2014, "An extension of MACBETH method for a fuzzy environment to analyze alternatives in reverse logistics for automobile tire wastes", Omega, 42(1): 25–32.
16. Rodrigues T.C., 2014, "The MACBETH Approach to Health Value Measurement: Building a Population Health Index in Group Processes", Procedia Technology, 16: 1361–1366.
17. Lavoie R., Deslandes J. and Proulx F., 2016, "Assessing the ecological value of wetlands using the MACBETH approach in Quebec City", Journal for Nature Conservation, 30: 67-75.
18. Ishizaka A. and Gordon M., 2017, "MACBETHSort: a multiple criteria decision aid procedure for sorting strategic products", Journal of the Operational Research Society, 68: 53–61.
19. Taguchi G., 1986, "Introduction to quality engineering: designing quality into products and processes", Asian productivity organization: Tokyo.

20. Azizi A., Yarmohammadi Y. and Yasini A., 2015, “Superior Supplier Selection - A Joint Approach of Taguchi, AHP, and Fuzzy Multi- Objective Programming”, Australian Journal of Basic and Applied Sciences, 9(2): 163–170.
21. Festervand T.A., Kethley R.B. and Waller B.D., 2001, “The marketing of industrial real estate: application of Taguchi loss functions”, Journal of Multi-Criteria Decision Analysis, 10(4): 219–228.
22. Liao C.N. and Kao H.P., 2010, “Supplier selection model using Taguchi loss function, analytical hierarchy process and multi-choice goal programming”, Computers & Industrial Engineering, 58(4): 571–577.
23. Ordoobadi S., 2009, “Application of Taguchi loss functions for supplier selection”, Supply Chain Management: An International Journal, 14(1): 22–30.
24. Pi W.N. and Low C., 2006, “Supplier evaluation and selection via Taguchi loss functions and an AHP” International Journal of Advanced Manufacturing Technology, 27(5–6): 625–630.
25. Sivakumar R., Kannan D. and Murugesan P., 2015, “Green vendor evaluation and selection using AHP and Taguchi loss functions in production outsourcing in mining industry”, Resources Policy, 46: 64–75.
26. Akman G., 2015, “Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods”, Computers and Industrial Engineering, 86: 69–82.
27. Ertay T., Kahraman C. and Kaya I., 2013, “Evaluation of renewable energy alternatives using MACBETH and fuzzy AHP multicriteria methods: the case of Turkey”, Technological and Economic Development of Economy, 19(1): 38–62.
28. Lee A.H.I., Kang H.Y., Hsu C.F. and Hung H.C., 2009, “A green supplier selection model for high-tech industry”, Expert Systems with Applications, 36: 7917-7927
29. Lu L.Y.Y., Wu C.H. and Kuo T.C., 2007, “Environmental principles applicable to green supplier evaluation by using multi-objective decision analysis”, International Journal of Production Research, 45(18-19): 4317-4331.
30. Bakeshlou E.A., Khamseh A.A., Asl M.A.G., Sadeghi J. and Abbaszadeh M., 2017, “Evaluating a green supplier selection problem using a hybrid MODM algorithm”, Journal of Intelligent Manufacturing, 28(4): 913-927.
31. Büyüközkan G. and Çifçi G., 2012, “A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers”, Expert Systems with Applications, 39(3): 3000–3011.
32. Hashemi S.H., Karimi A. and Tavana M., 2015, “An integrated green supplier selection approach with analytic network process and improved Grey relational analysis”, International Journal of Production Economics, 159: 178–191.
33. Hsu C.W. and Hu A.H., 2009, “Applying hazardous substance management to supplier selection using analytic network process”, Journal of Cleaner Production, 17: 255-264.
34. Kuo T.C., Hsu C.W. and Li J.Y., 2015, “Developing a green supplier selection model by using the DANP with VIKOR”, Sustainability, 7(2): 1661–1689.
35. Tuzkaya G., Özgen A., Özgen D. and Tuzkaya U.R., 2009, “Environmental performance evaluation of suppliers: A hybrid fuzzy multi-criteria decision approach”, International Journal of Environmental Science and Technology, 6(3): 477-490.
36. Awasthi A. and Kannan G., 2016, “Green supplier development program selection using NGT and VIKOR under fuzzy environment”, Computers and Industrial Engineering, 91: 100–108.
37. Banaeian N., Mobli H., Fahimnia B., Nielsen I.E. and Omid M., 2016, “Green Supplier Selection Using Fuzzy Group Decision Making Methods: A Case Study from the Agri-Food Industry”, Computers & Operations Research online publication 4 March. http://doi.org/10.1016/j.cor.2016.02.015
38. Rostamzadeh R., Govindan K., Esmaeili A. and Sabaghi M., 2015, “Application of fuzzy VIKOR for evaluation of green supply chain management practices”, Ecological Indicators, 49: 188–203.
39. Awasthi A., Chauhan S.S. and Goyal S.K., 2010, “A fuzzy multicriteria approach for evaluating environmental performance of suppliers”, International Journal of Production Economics, 126: 370-378.
40. Shen L., Olfat L., Govindan K., Khodaverdi R. and Diabat A., 2013, “A fuzzy multi criteria approach for evaluating green supplier’s performance in green supply chain with linguistic preferences”, Resources, Conservation and Recycling, 74: 170–179.
41. Yang Y. and Wu L., 2007, “Grey entropy method for green supplier selection”, In: IEEE International Conference on WiCom, 21-25 Sept, pp. 4682-4685.
42. Bala A., Paco Muñoz P., Rieradevall J. and Ysern P., 2008, “Experiences with greening suppliers. The Universitat Autònoma de Barcelona”, Journal of Cleaner Production, 16(15): 1610-1619.
43. Hong-Jun L. and Bin L., 2010, “A research on supplier assessment indices system of green purchasing”, In: IEEE International Conference on ICEE, 13-14 March, pp. 314-317.
44. Feyzioglu O. and Büyüközkan G., 2010, “Evaluation of green suppliers considering decision criteria dependencies”, In Ehrgott M, Naujoks B, Stewart TJ and Wallenius J (eds). Multiple Criteria Decision Making for Sustainable Energy and Transportation Systems. Springer-Verlag: Berlin, pp. 145-154.
45. Chiou T.Y., Chan H.K., Lettice F. and Chung S.H., 2011, “The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan”, Transportation Research Part E Logistics and Transportation Review, 47(6): 822-836.
46. Yeh W.C. and Chuang M.C., 2011, “Using multi-objective genetic algorithm for partner selection in green supply chain problems”, Expert Systems with Applications, 38: 4244-4253.
47. Zhao H. and Guo S., 2014, “Selecting Green Supplier of Thermal Power Equipment by Using a Hybrid MCDM Method for Sustainability”, Sustainability, 6: 217-235.
48. Dobos I. and Vörösmarty G., 2014, “Green supplier selection and evaluation using DEA-type composite indicators”, International Journal of Production Economics, 157(1): 273–278.
49. Kannan D, De Sousa Jabbour ABL and Jabbour CJC (2014). Selecting green suppliers based on GSCM practices: Using Fuzzy TOPSIS applied to a Brazilian electronics company. European Journal of Operational Research 233(2): 432–447.
50. Kannan D., Govindan K. and Rajendran S., 2015, “Fuzzy axiomatic design approach based green supplier selection: A case study from Singapore”, Journal of Cleaner Production, 96: 194–208.
51. Keshavarz Ghorabaee M., Zavadskas E.K., Amiri M. and Esmaeili A., 2016, “Multi-criteria evaluation of green suppliers using an extended WASPAS method with interval type-2 fuzzy sets”, Journal of Cleaner Production, 137: 213–229.
52. Rezaei J., Nispeling T., Sarkis J. and Tavasszy L., 2016, “A supplier selection life cycle approach integrating traditional and environmental criteria using the best worst method”, Journal of Cleaner Production, 135: 577–588.
53. Bana e Costa C.A. and Vansnick J.C., 1997, “Applications of the MACBETH approach in the framework of an additive aggregation model”, Journal of Multi-criteria Decision Analysis, 6(2): 107-114.
54. Burgazoğlu H., 2015, “MACBETH”, In Yıldırım BF and Önder E (eds). Çok kriterli karar verme yöntemleri. Dora Yayıncılık: Ankara, pp. 259-278.
55. Clivillé V., Berrah L. and Mauris G., 2007, “Quantitative expression and aggregation of performance measurements based on the MACBETH multi-criteria method”, International Journal of Production Economics, 105(1): 171–189.
56. Bana e Costa C.A., De Corte J.M. and Vansnick J.C., 2005, “M-MACBETH User’s Guide (Version 2.4.0)”, http://www.m-macbeth.com/help/pdf/M-MACBETH 2.4.0 Users Guide.pdf, accessed 26 December 2016.
57. Gören Güner H., 2018, “A decision framework for sustainable supplier selection and order allocation with lost sales”, Journal of Cleaner Production, 183: 1156-1169.