A Fuzzy Logic Based Green Performance Evaluation Model for Automotive Industry

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Abstract

Nowadays, increasing manufacturing activities cause to critical environmental problems such as global warming and air pollution. These environmental problems have provided increase of environmental awareness in the production process and therefore the green manufacturing (GM) concept has emerged. In general, this concept refers to a production process, which has high efficiency and minimum environmental damage in terms of resources and products. GM has recently become important in almost every sector. Automotive industry has significant importance in terms of economy and employment when considered its sub-industry and other related sectors. Therefore, it is important to evaluate the adoption level of green manufacturing concept in this sector. Fuzzy multi criteria decision making (FMCDM) methods which handle uncertainty in decision making problems can be effectively used for green performance evaluation of companies. In this study, it is aimed to assess green performance of manufacturers which operate in automotive sector by using a MCDM model based on fuzzy analytic hierarchy process (FAHP) method. This model consists of 5 main criteria which are green design, green energy, green material, green logistics and green management, and 19 sub criteria located under these main criteria. As a result of the study, green energy and low waste criteria were determined as the most important main and sub criteria with weights of 0.268 and 0.1026 respectively. The proposed model can be used as an effective tool for companies operating in the automotive industry to measure and to follow their green performance and to select their suppliers.

Keywords: Fuzzy MCDM, Green manufacturing, Fuzzy AHP, Automotive industry.

1. Introduction

Increasing production activities in order to meet high demands generating from rapid population growth, lead to many environmental problems such as global warming and ozone layer depletion. These environmental problems that arise as a result of air, water and soil pollutions jeopardize environmental sustainability and threaten the future of our world (Anderson et al., 2016). In addition, it is necessary to use natural resources more efficiently due to rapid decrease of them with increasing population.

Nowadays, environmental concerns affect almost all organizations at the administrative and operational level (Govindan et al., 2015). National and international legal regulations, governmental and non-governmental organizations and increasing awareness of environmental protection among people force companies to act with an environmental approach while conducting their activities (Buyukozkan and Cifci, 2012). As a result of these increasing pressures about the environment, greening have become one of the major trends in production in recent years. At this point, green manufacturing can be defined as having an environmental point of view at every stage of production process.

One of the purposes of GM practices is to reduce the carbon footprint of companies. Developing policies for reducing carbon footprint which is related to CO_2 equivalent (CO_2e) gases emitted during all stages of production is quite important in terms of an environment oriented production. CO_2e gases cause global warming which is one of the most crucial problems facing our world (Bhattacharya et al., 2015; Hussain et al., 2017). Environmental pollution, on the other hand, is an important problem which threats human life (Kamacı and Uysal, 2017). In this context, GM studies aim to decrease environmental pollution.

Automotive industry is a big customer of different sectors such as iron and steel, light metals and chemical industries. It provides a large business volume with many suppliers and creates employment opportunities for many people (Dweiri et al., 2016). In addition, automotive sector is one of the largest sectors in the world and has a considerable impact on the environment. Therefore, assessment of green manufacturing adoption levels of manufacturers in this sector is important for the environment.

In this study, we aimed to create a green performance evaluation model based on fuzzy AHP method for manufacturers in the automotive sector. Fuzzy set theory (FST) is used with AHP method so as to handle the qualitative and imprecise data concurrently. The proposed model which has the flexibility to be applied for different manufacturers, presents an important tool for companies to measure their own green performance and enables to select their suppliers.

The rest of this paper is organized as follows. A literature review related to green manufacturing has been given in Section 2. Fuzzy AHP method which used as a MCDM method has been explained in Section 3. The proposed green performance evaluation model has been presented in Section 4. Conclusions and future suggestions are in Section 5.

2. Literature Review

There are many MCDM studies with respect to green manufacturing applications in the literature. Some of these studies are briefly summarized as follows. Çifçi and Büyüközkan (2011), suggested a group MCDM framework utilizing fuzzy AHP method for green supplier selection (GSS) problem. Tseng (2011), aimed to determine the most suitable alternative through linguistic preferences under incomplete information by using green supply chain management (GSCM) criteria. The weights of criteria and alternatives are determined via fuzzy set theory. Büyüközkan (2012), proposed an integrated fuzzy MCDM methodology including fuzzy AHP and fuzzy Axiomatic Design (AD) methods in order to evaluate green performance of suppliers. Tseng and Chiu (2013), studied on supplier selection problem as an indicator of environmentally sensitive manufacturing. They ranked alternative suppliers by means of grey relational analysis (GRA) method. Mittal and Sangwan (2014), applied fuzzy TOPSIS method so as to prioritize green manufacturing (GM) drivers by evaluating in terms of social, environmental and economic aspects. Banaeian et al. (2015), aimed to determine criteria for GSS problem in food industry. AHP and Delphi methods are used for weighting criteria and collecting of sub-criteria by an expert team. They applied fuzzy GRA method in order to rank green suppliers. Bhattacharya et al. (2015), provided an overview related to GM supply chain design and decision support to help researchers studied in this field. Govindan et al. (2015), proposed a MCDM methodology integrating DEMATEL based ANP (DANP) and PROMETHEE methods for selecting the best green manufacturing practices. Govindan et al. (2015), aimed to prioritize the drivers of green manufacturing using fuzzy AHP method. They performed a sensitivity analysis by using different defuzzification methods. Ilgin et al. (2015), presented a literature review study including 190 MCDM papers related to environmentally sensitive manufacturing. They divided into them three major categories in order to inform researchers about this field. Ghorabaee et al. (2016), applied interval type-2 fuzzy Weighted Aggregated Sum Product Assessment (WASPAS) method for green supplier evaluation problem. They performed a sensitivity analysis by using different criteria weights and different parameters in order to reveal stability of the proposed method. Kumar et al. (2016), suggested a novel methodology named as Genetic/Immune Strategy for Data Envelopment Analysis (GIS/DEA) so as to solve GSS problem. Liao et al. (2016), applied a MCDM methodology combining fuzzy AHP, fuzzy additive ratio assessment (ARAS-F) and multi-segment goal programming (MSGP) for evaluating GSS problem. Yazdani et al. (2016), utilized a combined model including SWARA, QFD and WASPAS methods for GSS problem. They used SWARA method so as to give more weight to customer requirements and QFD for transforming customer requirements into supplier evaluation index. At the end of the study, they ranked alternative suppliers by using WASPAS method. Salem and Deif (2017), suggested Greenometer which is a toolbox in order to evaluate greenness level of manufacturing companies. They used data envelopment analysis as a decision making method in this study.

3. Fuzzy AHP Method

Analytic hierarchy process (AHP) and analytic network process (ANP) methods have been developed by Saaty as hierarchical and pairwise comparison based decision making methods (Saaty, 1977; Saaty, 2001; Saaty, 2008).

AHP which presents a useful methodology for MCDM deals with problem in a hierarchical structure (Wang and Chin, 2011). Generally, 1-9 scale proposed by Saaty for establish pairwise comparison matrices are used in AHP method (Ugur and Baykan, 2017). However, crisp values are insufficient to express human thinking and judgment which constitute input for problem. Thus, fuzzy AHP methodology has been developed with use of fuzzy numbers instead of crisp numbers (Kusumawardani and Agintiara, 2015).

AHP and its extension fuzzy AHP methods are commonly utilized for different decision making problems such as manufacturing plant sustainability evaluation (Jayawickrama et al., 2017), mineral prospectivity mapping (Zhang et al., 2017), organ transplantation (Yuen, 2014), evaluation of in-flight service quality (Li et al., 2017) and shipping technology selection (Sahin and Yip, 2017). On the other hand, AHP and fuzzy AHP methods are applied with together another MCDM methods as shown in (Karatas, 2017; Otay et al., 2017; Karatas et al., 2018).

One of the most popular fuzzy AHP methods is Chang's approach named as extent analysis method (Heo et al., 2012). The triangular fuzzy conversion scale utilized in this method for pairwise comparison is given in Table 1.

Table 1. Linguistic expressions and corresponding triangular fuzzy numbers (TFNs) (Esen et al.,2016; Erdem, 2016; Toklu, 2017)

Linguistic Expressions	Fuzzy Scale	Fuzzy Reciprocal Scale
Equally Important (EI)	(1,1,1)	(1,1,1)
Weakly Important (WI)	(1,3,5)	(1/5,1/3,1)
Strongly Important (SI)	(3,5,7)	(1/7,1/5,1/3)
Very Important (VI)	(5,7,9)	(1/9,1/7,1/5)
Absolutely Important (AI)	(7,9,9)	(1/9,1/9,1/7)

The extent analysis method is explained as follows (Esen et al.,2016; Erdem, 2016).

$C = \{C_1, C_2, ..., C_n\}$ is a criteria set and $A = \{A_1, A_2, ..., A_m\}$ is an alternative set, where n and m are the number of criteria and alternatives respectively. Extent analysis for each criteria C_i is performed, respectively. Thus, m extent analysis values for each alternative can be calculated as follows:

$$M_{C_i}^1, M_{C_i}^2, ..., M_{C_i}^m, \qquad i = 1, 2, ..., n \qquad (1)$$

where all of $M_{C_i}^j$, $(j = 1, 2, ..., m)$ values are obtained as TFNs.

Step 1: Fuzzy synthetic extent value for ith object is calculated as follows:

$$S_i = \sum_{j=1}^{m} M_{C_i}^j \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{C_i}^j \right]^{-1} \qquad (2)$$

$$\sum_{j=1}^{m} M_{C_i}^j = \left(\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j \right) \qquad (3)$$

$$\sum_{i=1}^{n} \sum_{j=1}^{m} M_{C_i}^j = \left(\sum_{i=1}^{n} l_i, \sum_{i=1}^{n} m_i, \sum_{i=1}^{n} u_i \right) \qquad (4)$$

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M_{C_i}^j \right]^{-1} = \left(\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i} \right) \qquad (5)$$

where, $\otimes$ indicates fuzzy multiplication operator.

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined as;

$$V(M_2 \geq M_1) = \sup_{s \geq t} \left[\min \mu_{M_1}(s), \mu_{M_2}(t) \right] \qquad (6)$$

and can be equivalently expressed as follows:

$$V(M_2 \geq M_1) = hgt(M_1 \cap M_2) =$$

$$\mu_{M_2}(d) \begin{cases} 1, & if \ m_2 \geq m_1 \\ 0, & if \ l_1 \geq u_2 \\ \frac{l_1-u_2}{(m_2-u_2)-(m_1-l_1)} & otherwise \end{cases} \quad (7)$$

where d is the ordinate of the highest intersection point D between μ_{M_1} and μ_{M_2} as seen in Figure 1. To compare M_1 and M_2, we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$.
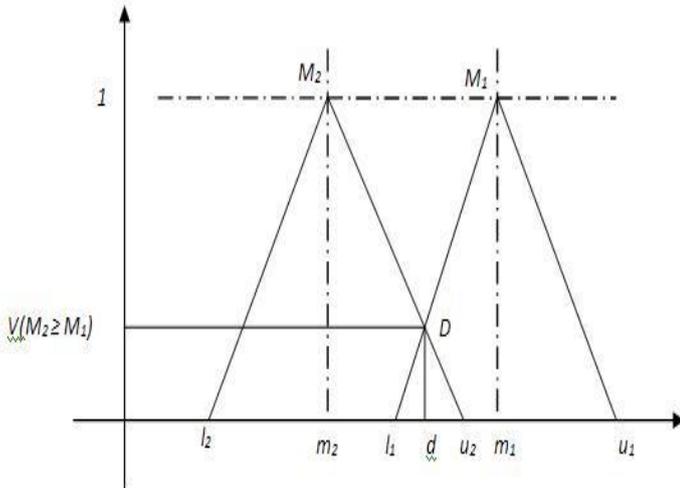
Figure 1. The intersection between M_1 and M_2 (Esen et al., 2016).

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers M_i $(i = 1, 2, ., k)$ can be defined as follows:

$$V(M \geq M_1, M_2, ..., M_k) = V[(M \geq M_1) \ and \ (M \geq M_2) \ and \ ... \ and \ (M \geq M_k)]$$

$$= min \ V(M \geq M_i), \ i = 1, 2, ..., k \quad (8)$$

Assume that

$$d'(A_i) = min \ V(S_i \geq S_k) \quad (9)$$

then the weight vector for k = 1, 2, …, n; k ≠ i is given by following equation;

$$W' = (d'(A_1), d'(A_2), ..., d'(A_n))^T \quad (10)$$

Step 4: The normalized weight vectors are obtained as crisp number through normalization.

$$W = (d(A_1), d(A_2), ..., d(An))^T \quad (11)$$

4. The Proposed Evaluation Model

In this section, a green performance evaluation model based on fuzzy AHP method is suggested in order to evaluate companies operating in automotive industry. It is aimed to provide an effective tool for these companies to evaluate green performance of them and their suppliers. In this context, the green performance evaluation criteria are determined by means of literature review and expert opinions (Chithambaranathan et al., 2015; Rostamzadeh et al., 2015; Govindan et al., 2015; Uygun and Dede, 2016; Salem and Deif, 2017; Luthra et al., 2017). These criteria are presented as a two stage hierarchical structure in Figure 2.
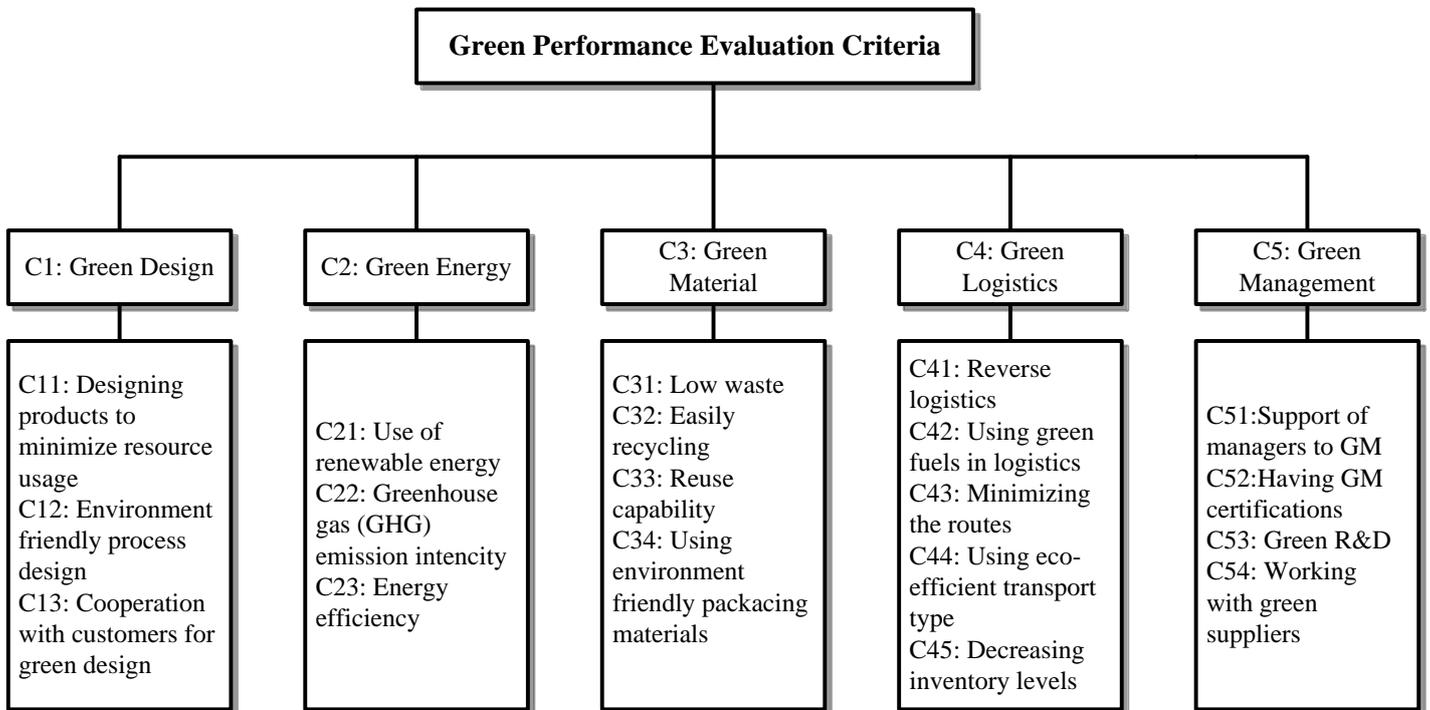
Figure 2. The hierarchical structure for green performance evaluation model

In the scope of this study, 5 main criteria and 19 sub-criteria are determined in order to use in green performance evaluation model. Green design, green energy, green material, green logistics and green management are handled as main criteria. Green design includes three sub-criteria as designing products to minimize

resource usage, environment friendly process design and cooperation with customers for green design. It is aimed to evaluate production process of companies in terms of environment friendly design by using these criteria. Green energy also includes three sub-criteria as usage of renewable energy,

GHG emission intensity and energy efficiency. These criteria emphasize the importance of using renewable energy in production process and assess alternatives according to their clean energy usage. Green material is a main criterion which includes four sub-criteria as low waste, easily recycling, reuse capability and using environment friendly packaging materials. These criteria aim to evaluate manufacturers in terms of using green materials in the production process. Besides, green logistics is an important main criterion for green performance evaluation. It includes five sub-criteria as reverse logistics, using green fuels in logistics, minimizing the routes, using eco-efficient transportation type and decrease inventory levels. These criteria aim to assess logistics activities of companies according to environmental awareness. Finally, green management criterion includes support

of managers to GM, having GM certifications, Green R&D and working with green suppliers criteria. It is aimed to assess companies at managerial level by using these criteria.

Firstly, pairwise comparison matrices (PCMs) are formed for main and sub criteria in order to determine weights of evaluation criteria by using expert opinions. The matrices are filled by three experts who are from academia. These experts have studies related to fuzzy logic and they have information about automotive industry. The expert evaluations for main criteria are presented in Table 2. Expert evaluations are aggregated via geometric mean. The aggregated fuzzy decision matrix for main criteria is given in Table 3.

Table 2. The expert evaluations for main criteria.

	C1			C2			C3			C4			C5		
	Exp 1	Exp 2	Exp 3	Exp 1	Exp 2	Exp 3	Exp 1	Exp 2	Exp 3	Exp 1	Exp 2	Exp 3	Exp 1	Exp 2	Exp 3
C1	EI	EI	EI	WI	1/VI	1/SI	EI	1/SI	1/WI	SI	1/SI	1/WI	EI	1/AI	WI
C2	1/WI	VI	SI	EI	EI	EI	1/WI	WI	EI	WI	WI	WI	EI	1/WI	SI
C3	EI	SI	WI	WI	1/WI	EI	EI	EI	EI	WI	EI	WI	EI	1/SI	VI
C4	1/SI	SI	WI	1/WI	1/WI	1/WI	1/WI	EI	1/WI	EI	EI	EI	1/SI	1/SI	WI
C5	EI	AI	1/WI	EI	WI	1/SI	EI	SI	1/VI	SI	SI	1/WI	EI	EI	EI

Table 3. The aggregated fuzzy decision matrix for main criteria.

	C1			C2			C3			C4			C5		
C1	1.00	1.00	1.00	0.25	0.44	0.69	0.31	0.41	0.69	0.44	0.69	1.33	0.48	0.69	0.89
C2	1.44	2.27	3.98	1.00	1.00	1.00	0.58	1.00	1.71	1.00	3.00	5.00	0.84	1.19	1.91
C3	1.44	2.47	3.27	0.58	1.00	1.71	1.00	1.00	1.00	1.00	2.08	2.92	0.89	1.12	1.44
C4	0.75	1.44	2.27	0.20	0.33	1.00	0.34	0.48	1.00	1.00	1.00	1.00	0.27	0.49	0.82
C5	1.12	1.44	2.08	0.52	0.84	1.19	0.69	0.89	1.12	1.22	2.03	3.66	1.00	1.00	1.00

Similarly, the aggregated fuzzy decision matrices are obtained for all of sub-criteria. Afterwards, the criteria weights for main and sub criteria are calculated by using these aggregated fuzzy decision matrices. The criteria weights obtained as a result of fuzzy AHP calculations are given as crisp numbers in Table 4. Besides, the graphical demonstration of main criteria weights is presented in Figure 3.

Table 4. The weights of Evaluation Criteria

Main Criteria	Weights	Sub-Criteria	Local Weights	Global Weights
C1	0.111	C11	0.517	0.0574
		C12	0.455	0.0505
		C13	0.028	0.0031
C2	0.268	C21	0.370	0.0992
		C22	0.370	0.0992
		C23	0.260	0.0697
C3	0.252	C31	0.407	0.1026
		C32	0.302	0.0761
		C33	0.168	0.0423
		C34	0.123	0.0310
C4	0.149	C41	0.223	0.0332
		C42	0.149	0.0222
		C43	0.219	0.0326
		C44	0.222	0.0331
		C45	0.187	0.0279
C5	0.220	C51	0.289	0.0636
		C52	0.128	0.0282
		C53	0.341	0.0750
		C54	0.242	0.0532
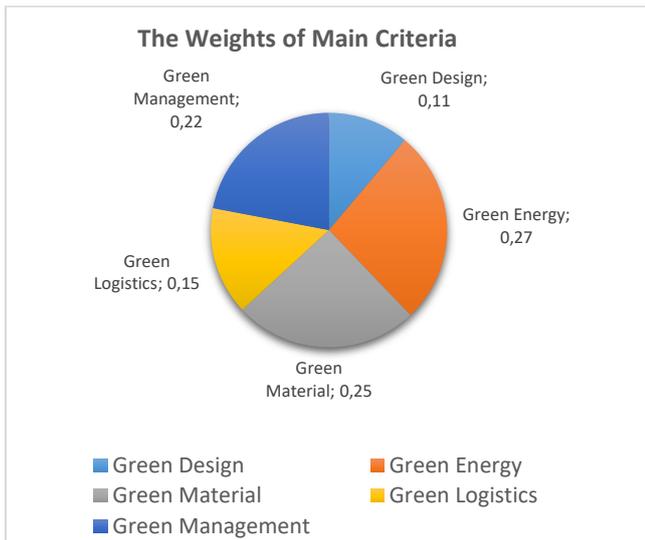
Figure 3. The graphical demonstration of main criteria weights

According to results, the main criteria are ranked as green energy, green material, green management, green logistics and green design respectively. As it is seen in this rank, green energy criterion was selected as the most significant one among main criteria with the weight of 0.268. Use of renewable energy and greenhouse gas emission criteria were selected as the most important sub-criteria related to this criterion. Besides, green design criterion was selected as the least important one with the weight of 0.111. On the other hand, low waste criterion was selected as the most important sub-criterion with the weight of 0.1026.

5. Conclusions and Suggestions

In parallel with the population growth, the increase in production activities leads to environmental pollution in every respect and therefore to irreversible environmental degradation. This degradation is accompanied by environmental disasters such as ozone depletion and global warming that threaten living things in dangerous extent. Increasing environmental awareness, especially with the emerging environmental problems in the last decade, forces every large-scale company to include environmentalist thinking at every stage of production process, and therefore to minimize the harm it gives the environment while performing its production activities.

In this study, a green performance assessment model has been presented for companies operating in the automotive industry which is one of the leading sectors of many countries with its suppliers and high business volume. The model, which is constructed using the AHP method integrated with the fuzzy approach, consists of 5 main criteria including green design, green energy, green material, green logistics and green management and 19 sub criteria. Green energy is the main criterion with the highest weight of 0.268 according to the model which is constructed by taking the evaluations of different experts. The proposed model provides an important tool for companies in the automotive industry to measure and follow their own green performance and to select their suppliers. It is possible to obtain a green performance score for companies and their suppliers by using this model. In the future studies, the scope of the model can be expanded by increasing the main and sub criteria. In addition to this, similar models can be created for green performance assessment for different sectors.

References

Anderson, T.R., Hawkins, E., Jones, P.D. 2016. CO_2, the greenhouse effect and global warming: from the pioneering work of Arrhenius and Callendar to today's Earth System Models. Endeavour 40(3), 178-187.

Banaeian, N., Mobli, H., Nielsen, I.E., Omid, M. 2015. Criteria definition and approaches in green supplier selection – a case study for rew material and packaging of food industry. Production & Manufacturing Research 3(1), 149-168.

Bhattacharya, A., Dey, P.K., Ho, W. 2015. Green manufacturing supply chain design and operations decision support. International Journal of Production Research 53(21), 6339-6343.

Buyukozkan, G. 2012. An integrated fuzzy multi-criteria group decision-making approach for green supplier evaluation. International Journal of Production Research 50(11), 2892-2909.

Buyukozkan, G., Cifci, 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.

Chithambaranathan, P., Subramanian, N., Gunasekaran, A., Palaniappan, P.L.K. 2015. Service supply chain environmental performance evaluation using grey based hybrid MCDM approach. Int. J. Production Economics 166(1), 163-176.

Çifçi, G., Büyüközkan, G. 2011. A Fuzzy MCDM Approach to Evaluate Green Suppliers. International Journal of Computational Intelligence Systems 4(5), 894-909.

Dweiri, F., Kumar, S., Khan, S.A., Jain, V. 2016. Designing an integrated AHP based decision support system for supplier selection in automotive industry. Expert Systems with Applications 62(1), 273-283.

Erdem, M.B. 2016. A Fuzzy Analytical Hierarchy Process Application in Personnel Selection in IT Companies: A Case Study in a Spin-off Company. Acta Physica Polonica A 130(1), 331-334.

Esen, H., Hatipoğlu, T., Boyacı, A.İ., 2016. A Fuzzy Approach for Performance Appraisal: The Evaluation of a Purchasing Specialist, Computational Intelligence, Studies in Computational Intelligence 620, Springer International Publishing, 237s, Switzerland.

Ghorabaee, M.K., Zavadskas, E.K., Amiri, M., 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(1), 213-229.

Govindan, K., Diabat, A., Shankar, K.M. 2015. Analyzing the drivers of green manufacturing with fuzzy approach. Journal of Cleaner Production 96(1), 182-193.

Govindan, K., Kannan, D., Shankar, M. 2015. Evaluation of green manufacturing practices using a hybrid MCDM model combining DANP with PROMETHEE. International Journal of Production Research 53(21), 6344-6371.

Govindan, K., Khodaverdi, R., Vafadarnikjoo, A. 2015. Intuitionistic fuzzy based DEMATEL method for developing green practices and performances in a green supply chain. Expert Systems with Applications 42(20), 7207-7220.

Heo, E., Kim, J., Cho, S. 2012. Selecting hydrogen production methods using fuzzy analytic hierarchy process with opportunities, costs, and risks. International Journal of Hydrogen Energy 37(23), 17655–17662.

Hussain, M., Malik, R.N., Taylor, A. 2017. Carbon footprint as an environmental sustainability indicator for the particleboard

produced in Pakistan. Environmental Research 155(1), 385–393.

Ilgin, M.A., Gupta, S.M., Battaia, O. 2015. Use of MCDM techniques in environmentally conscious manufacturing and product recovery: State of the art. Journal of Manufacturing Systems 37(3), 746-758.

Jayawickrama, H.M.M.M., Kulatunga, A.K., Mathavan, S. 2017. Fuzzy AHP based Plant Sustainability Evaluation Method. Procedia Manufacturing 8, 571-578.

Kamacı, Z., Uysal, G. 2017. Pollution Determined by Using Magnetic Susceptibility Measurements: A Case Study from İzmir-Aliağa. Acta Physica Polonica A 132(3), 487-489.

Karatas, M. 2017. Multiattribute Decision Making Using Multiperiod Probabilistic Weighted Fuzzy Axiomatic Design. Systems Engineering 20(4), 318-334.

Karatas, M., Sulukan, E., Karacan, I. 2018. Assessment of Turkey's energy management performance via a hybrid multi-criteria decision-making methodology. Energy 153, 890-912.

Kumar, A., Jain, V., Kumar, S., Chandra, C. 2016. Green supplier selection: a new genetic/immune strategy with industrial application. Enterprise Information Systems 10(8), 911-943.

Kusumawardani, R.P., Agintiara, M. 2015. Application of Fuzzy AHP-TOPSIS Method for Decision Making in Human Resource Manager Selection Process. Procedia Computer Science 72(1), 638–646.

Li, W., Yu, S., Pei, H., Zhao, C., Tian, B. 2017. A hybrid approach based on fuzzy AHP and 2-tuple fuzzy linguistic method for evaluation in-flight service quality. Journal of Air Transport Management 60, 49-64.

Liao, C.N., Fu, Y.K., Wu, L.C. 2016. Integrated FAHP, ARAS-F and MSGP Methods for Green Supplier Evaluation and Selection. Technological and Economic Development of Economy 22(5), 651-669.

Luthra, S., Govindan, K., Kannan, D., Mangla, S.K., Garg, C.P. 2017. An integrated framework for sustainable supplier selection and evaluation in supply chains. Journal of Cleaner Production 140(3), 1686-1698.

Mittal, V.K., Sangwan, K.S. 2014. Prioritizing Drivers for Green Manufacturing: Environmental, Social and Economic Perspectives. Procedia CIRP 15(1), 135-140.

Otay, I., Oztaysi, B., Cevik Onar, S., Kahraman, C. 2017. Multi-expert performance evaluation of healthcare institutions using an integrated intuitionistic fuzzy AHP&DEA methodology. Knowledge-Based Systems 133, 90-106.

Rostemzadeh, R., Govindan, K. 2015. A. Esmaeili, M. Sabaghi, Application of fuzzy VIKOR for evaluation of green supply chain management practices. Ecological Indicators 49(1), 188-203.

Saaty, T.L. 1977. A scaling method for priorities in hierarchical structures. Journal of Mathematical Psychology 15(3), 234-281.

Saaty, T.L. 2001. Decision Making with Dependence and Feedback: The Analytic Network Process: The Organization and Prioritization of Complexity. Rws Publications, 370 pages.

Saaty, T.L. 2008. Decision making with the analytic hierarchy process. International Journal of Services Sciences 1(1), 83-98.

Sahin, B., Yip, T.L. 2017. Shipping technology selection for dynamic capability based on improved Gaussian fuzzy AHP model. Ocean Engineering 136, 233-242.

Salem, A.H., Deif, A.M. 2017. Developing a Greenometer for green manufacturing assessment. Journal of Cleaner Production 154(1), 413-423.

Toklu, M.C. 2017. Determination of Customer Loyalty Levels by Using Fuzzy MCDM Approaches. Acta Physica Polonica A 132(3), 650-654.

Tseng, M.L. 2011. Green supply chain management with linguistic preferences and incomplete information. Applied Soft Computing 11(8), 4894-4903.

Tseng, M.L., Chiu, A.S.F. 2013. Evaluating firm's green supply chain management in linguistic preferences. Journal of Cleaner Production 40(1), 22-31.

Ugur, L.O., Baykan, U. 2017. A Model Proposal for Wall Material Selection Decisions by Using Analytic Hierarchy Process (AHP). Acta Physica Polonica A 132(3), 577-579.

Uygun, O., Dede, A. 2016. Performance evaluation of green supply chain management using integrated fuzzy multi-criteria decision-making techniques. Computers & Industrial Engineering 102(1), 502-511.

Wang, Y.M., Chin, K.S. 2011. Fuzzy analytic hierarchy process: A logarithmic fuzzy preference programming methodology. International Journal of Approximate Reasoning 52(4), 541–553.

Yazdani, M., Zolfani, S.H., Zavadskas, E.K. 2016., E.K. New Integration of MCDM methods and QFD in the selection of green suppliers. Journal of Business Economics and Management 17(6), 1097-1113.

Yuen, KKF. 2014. The Least Penalty Optimization Prioritization Operators for the Analytic Hierarchy Process: A Revised Case of Medical Decision Problem of Organ Transplantation. Systems Engineering 17, 442-461.

Zhang, N., Zhou, K., Du, X. 2017. Application of fuzzy logic and fuzzy AHP to mineral prospectivity mapping of porphyry and hydrothermal vein copper deposits in the Dananhu-Tousuquan island arc, Xinjiang, NW China. Journal of African Earth Sciences 128, 84-96.