With the ability to publish proceedings from events of any size, MSE provides a comprehensive solution for materials science and engineering conferences

Latest volume
Vol 427, Mineral Engineering Conference 26-29 September 2018, Zawiercie, Poland

All 2018 volumes

Latest published conferences

Vol 427 ▼

Conference archive

2018 ▼

View forthcoming conferences accepted for publication.

IOP Conf. Ser.: Mater. Sci. Eng. (2009 - present) ▼ | Volume | Article or pag

Editorial & news

If you would like more information regarding *IOP Conference Series: Materials Science and Engineering* please visit conferenceseries.iop.org, and if you are interested in publishing a proceedings with IOP Conference Series please visit our page for conference organizers.

- **Conference organizers** can use our online form and we will get in touch with a quote and further details.
- **Researchers** will enjoy the conference-based search system to quickly find and browse proceedings of interest. Search through all proceedings by conference title, subject area and conference date / location.

Most read | Most cited | Latest articles

View all abstracts

OPEN ACCESS

Study the effect of cooling medium on the torsion resistance and hardness of medium carbon steel

Ahmed M. Abaas *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **405** 012005

IOP Publishing

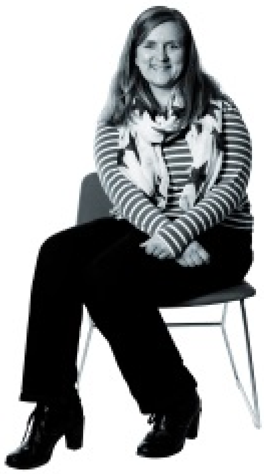
Get new quote

IOP Conference Series team

Anete Ashton
Publisher, Conference Series

Anete Ashton is the Publisher for the proceedings programme at IOP Publishing. With an MA in linguistics and over ten years' experience in proceedings publication she has developed and grown the IOP Conference Series and has commissioned some of the most prestigious conferences in physics and related subject areas.

E-mail Anete Ashton
Tel +44 (0)117 930 1280



Steph Gill
Conference Publishing Co-ordinator

Steph looks after the day-to-day operations of IOP Conference Series, including commissioning content and liaising with conference organizers/editors. Steph joined the Conference Series team after eight years in the Production department. She has a degree in Media and Film from the University of Winchester.

E-mail Steph Gill
Tel +44 (0)117 930 1252

Kayleigh Parsons
Editorial Assistant, Conference Series

Kayleigh works three days a week with the operations of IOP Conference Series, including system organisation and point of contact for organisers/editors. Kayleigh joined IOP Publishing back in 2008 working in Publishing, she then took 18 months off to travel but re-joined the company in 2015. Kayleigh then joined the Conference Series team in 2018.

E-mail Kayleigh Parsons
Tel +44 (0)117 930 1252 or 1280

Svetlana Kalinina
Technical Production Editor

Svetlana Kalinina is a Production Editor who coordinates the online and print production of proceedings for IOP Conference Series journals. She joined IOP in January 2002. She has a degree in genetics from St.Petersburg State University.

Contact us

Publication procedure and editorial questions can be sent to the individual journal e-mail addresses:

- *Journal of Physics: Conference Series*
  jpcs@iop.org
- *IOP Conference Series: Materials Science and Engineering*
  mse@iop.org
- *IOP Conference Series: Earth and Environmental Science*
  ees@iop.org
- Or to the general address:
  conferenceseries@iop.org

Committee

Chair

Dr. Mohammad Mi`radj Isnaini (Bandung Institute of Technology, Indonesia)

The Conference Co-Chairs

Bandung Institute of Technology

Prof. Abdul Hakim Halim
Prof. Dradjad Irianto

Universiti Malaysia Pahang

Assoc. Professor Dr. Ahmad Razlan Yusoff
Dr. Muhammed Nafis Osman Zahid

Steering and Organizing Committee

Bandung Institute of Technology

Dr. Anas Ma`ruf
Prof. Bermawi Priyatna Iskandar
Mr. Fariz Muharram Hasby
Dr. Iwan Inrawan Wiratmadja
Mr. Muhammad Akbar
Dr. Rachmawati Wangsaputra
Dr. Sukoyo
Dr. TMA. Ari Samadhi
Mr. Wildan Trusaji
Dr. Wisnu Aribowo

Universiti Malaysia Pahang

Dr Ahmad Shahrizan Abdul Ghani
Prof. Dato' Dr. Daing Nasir Ibrahim
Assoc. Professor Dr. Ismed Iskandar
Dr. Mohd Azmir Mohd Azhari
Mr. Mohd Khairulnazri bin Saidi
Dr. Nafrizuan Mat Yahya
Prof. Ir. Dr. Wan Azhar Wan Yusoff
Dr. Zamzuri Hamedon
Mr. Zulkifli Md. Yusof
Ms. Zuryaty binti Zol

International Scientific Committee

- Prof. A.K. Prasada Rao (BML Munjal University, India)
- Prof. Abdul Hakim Halim (Bandung Institute of Technology, Indonesia)
- Prof. Ahsan Ali Khan (International Islamic University Malaysia, Malaysia)
- Dr. Amelia Santoso (University of Surabaya, Indonesia)
- Prof. (Anthony) Shun Fung CHIU (De La Salle University, Phillipines)
- Prof. Bermawi Priyatna Iskandar (Bandung Institute of Technology, Indonesia)
- Prof. Che Hassan Che Haron (National University of Malaysia, Malaysia)
- Dr. Cucuk Nur Rosyidi (Sebelas Maret University, Indonesia)
- Dr. Delia J. Valles-Rosales (New Mexico State University, United States of America)
- Prof. Dradjad Irianto (Bandung Institute of Technology, Indonesia)
- Dr. Dida Diah Damayanti (Telkom University, Indonesia)
- Dr. Docki Saraswati, M.Eng (Trisakti University, Indonesia)

- I Made Dana Tangkas, M.Si.(Institut Otomotif Indonesia, Indonesia)
- Prof. I.S. Jawaher (University of Kentucky, United States of America)
- Prof. Ir. Isti Surjandari P., MT., Ph.D (University of Indonesia, Indonesia)
- Dr. Iwan Inrawan Wiratmadja (Bandung Institute of Technology, Indonesia)
- Prof. Kai Cheng (Brunel University London, United Kingdom)
- Prof. Katsuhiko Takahashi (Hiroshima University, Japan)
- Prof. Mani Maran Ratnam (University of Sciences Malaysia, Malaysia)
- Prof. Mohd. Adzir b. Mahdi (Universiti Putra Malaysia, Malaysia)
- Prof. Musa Mailah (Universiti Teknologi Malaysia, Malaysia)
- Dr. Muhammad Dirhamsyah (Syiah Kuala University, Indonesia)
- Prof. Niel D Sims (University of Sheffield, United Kingdom)
- Prof. Nik Abdullah Nik Mohamed (Universiti Malaysia Pahang, Malaysia)
- Dr. Nilda Tri Putri (University of Andalas, Indonesia)

- Dr. Nur Indriati (UPN `Veteran` Yogyakarta, Indonesia)
- Prof. Osman Tokhi (London South Bank University, United Kingdom)
- Prof. Raden Chairul Saleh (Islamic University of Indonesia, Indonesia)
- Prof. Robert Weiss (Karlsruhe University of Applied Sciences, Germany)
- Prof. Saleem Hashimi, (Dublin City University, Ireland)
- Prof. Shamsuddin Baharin (Universiti Malaysia Pahang, Malaysia)
- Prof. Shamsuddin Sulaiman (Universiti Putra Malaysia, Malaysia)
- Dr. The Jin Ai (Atma Jaya Catholic University of Indonesia, Indonesia)
- Dr. TMA. Ari Samadhi (Bandung Institute of Technology, Indonesia)
- Prof. Voratas Kachitvichyanukul, PhD (Asian Institute of Technology, Thailand)
- Prof. Wan Azhar Wan Yusoff (Universiti Malaysia Pahang, Malaysia)
- Prof. Zahari Taha (Universiti Malaysia Pahang, Malaysia)

Table of contents

Volume 319

2018

◂ Previous issue Next issue ▸

The 4th Asia Pacific Conference on Manufacturing Systems and the 3rd International Manufacturing Engineering Conference
7–8 December 2017, Yogyakarta, Indonesia

View all abstracts

Accepted papers received: 16 February 2018
Published online: 21 March 2018

Preface

Papers

OPEN ACCESS 012086

Design Of Measurements For Evaluating Readiness Of Technoware Components To Meet The Required Standard Of Products

Ilham Fauzi, Fariz Muharram Hasby and Dradjad Irianto

+ View abstract View article PDF

JOURNAL LINKS

Journal home

Information for organizers

Information for authors

Search for published proceedings

Contact us

Reprint services from Curran Associates

PAPER • **OPEN ACCESS**

An integrative multi-criteria decision making techniques for supplier evaluation problem with its application

To cite this article: D Fatrias *et al* 2018 *IOP Conf. Ser.: Mater. Sci. Eng.* **319** 012076

IOP Conf. Series: Materials Science and Engineering **319** (2018) 012076 doi:10.1088/1757-899X/319/1/012076

An integrative multi-criteria decision making techniques for supplier evaluation problem with its application

D Fatrias*, I Kamil and D Meilani

Dept. of Industrial Engineering, Universitas Andalas, Padang (25163), INDONESIA

*dickyf@eng.unand.ac.id

Abstract. Coordinating business operation with suppliers becomes increasingly important to survive and prosper under the dynamic business environment. A good partnership with suppliers not only increase efficiency, but also strengthen corporate competitiveness. Associated with such concern, this study aims to develop a practical approach of multi-criteria supplier evaluation using combined methods of Taguchi loss function (TLF), best-worst method (BWM) and VIse Kriterijumska Optimizacija kompromisno Resenje (VIKOR). A new framework of integrative approach adopting these methods is our main contribution for supplier evaluation in literature. In this integrated approach, a compromised supplier ranking list based on the loss score of suppliers is obtained using efficient steps of a pairwise comparison based decision making process. Implemetation to the case problem with real data from crumb rubber industry shows the usefulness of the proposed approach. Finally, a suitable managerial implication is presented.

1. Introduction

Among all strategic decision involved along enterprises' supply chain system, purchasing decision has a great impact on the overall system due to the fact that the cost of raw materials and component parts represents the largest percentage of the total product cost [1]. Establishing strong relationship with selected suppliers not only substantially reduces purchasing cost, but also significantly improves corporate competitiveness [2]. In today's business, however, many enterprises are still dealing with unreliable suppliers. Working with such suppliers may interrupt production, lower product availability and quality, and at the end, decrease enterprise competitiveness. Therefore, enterprises may initiate to develop their suppliers and try to actively improve the performance of their supplier base [3].

Supplier evaluation and selection are a crucial phase before supplier development. With an increasing occurrence of risk events, supplier evaluation and selection process become more and more important for the business. However, in practical decision making it is often found difficult to make a proper decision due to a complex and unstructured problem of supplier evaluation in nature involving quantitative and qualitative criteria simultaneously. To cope with such problem, enterprises can find utility in multi-attribute decision making (MADM) technique that can assist with evaluating and selecting suppliers. In this regard, several studies adopting MADM techniques have been proposed in literature. Jain et al. [4] proposed fuzzy multi-criteria decision-making model of supplier evaluation and selection where Analytical Hierarchy Process (AHP) is used to assign criteria weight and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is used to rank suppliers. Pitchipoo et al. [5] developed a decision support model for supplier evaluation and selection in the process industry by integrating AHP and Grey Relational Analysis (GRA). Yadav & Sharma [6] integrated Data Envelopment Analysis (DEA) into AHP procedures. Liu & Zang [7] proposed a novel integrated method of entropy weight and an improved ELECTRE-III to deal with supplier selection. Hsu et al. [8] developed a model to evaluate suppliers based on their carbon performance utilizing Analytical Network Process (ANP) to determine relative weights of each criterion and VIKOR to derive a compromised supplier ranking list. Chang et al. [9] proposed a novel approach of decision-making of supplier selection by applying fuzzy DEcision-MAking Trial and Evaluation Laboratory (DEMATEL) method to find influential factors in selecting suppliers. Parkouhi & Ghadikolaei [10] developed resilient approach to evaluate supplier using fuzzy ANP and grey-VIKOR. Chen et al. [11] investigated the use of The Preference Ranking Organization METHod for Enrichment of Evaluations (PROMETHEE) to evaluate suppliers in group decision making and fuzzy environment. Adali et al. [12] proposed an alternative version of fuzzy-PROMETHEE to solve supplier eavaluation problem in which preference functions are handled in terms of fuzzy distances between alternatives with respect to each criterion. Kuo et al. [13] developed integrated methods composed of DEMATEL and ANP to determine the relative importance of criteria and applied VIKOR to assess green suppliers. Gupta & Barua [14] proposed evaluate suppliers among SMEs (Small and Medium Enterprises) on the basis of their green innovation ability in which best-worst method is utilized to obtain criteria weights and fuzzy TOPSIS is used to rank the suppliers. Zeydan et al. [15] combined fuzzy-AHP, fuzzy TOPSIS and DEA to evaluate suppliers for automotive industry. Büyüközkan & Çifçi [16] proposed evaluation framework using hybrid approach of fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers.

This study relies on the theory of MADM from which integrated methods of TLF, BWM, and VIKOR technique are proposed to evaluate a set of suppliers. The TLF allows the DM to set performance target and its tolerance limit of suppliers for which the loss score of suppliers is calculated. The weight of criteria is computed using the most recent and efficient pairwise comparison – based method named BWM. Finally, a VIKOR's procedures are executed to rank the supplier. To examine its usefulness, the proposed research is implemented to solve the case from crumb rubber industry.

2. The proposed integrated approach

To structure appropriate steps of the proposed approach, each of the method used in this research is briefly discussed.

2.1. Taguchi loss function (TLF)

The original concept of TLF is based on quantifying the loss (in term of cost) incurs at customers if the quality characteristic of product deviates from the target value. Particularly, Taguchi proposes an acceptable quality definition that any deviation from quality's target value results in losses. The loss is zero when quality measurement is the same as the target value. Otherwise, such loss incurs whenever quality measurement fall within specification limit.

When $L(x)$ denotes the loss for quality characteristic x, and k is a loss constant factor, then the formulation for "larger is better" loss function is given in Eq. (1).

$$L(x)=\begin{cases} k\times(\dfrac{1}{x^2})^2 & \text{for single data} \\ k\times\left(\text{MSD}=\dfrac{1}{n}\sum_{i=1}^{n}(\dfrac{1}{x_i^2})^2\right) & \text{for } n-\text{data}\end{cases} \quad ; \quad k=100\%\times(T)^2 \tag{1}$$

2.2. Best-worst method (BWM)

Best-worst method (BWM) is a novel pairwise comparison based method proposed by Rezaei [17]. The steps of BWM start by first identifying a set of decision n criteria $\{c_1, c_2, ..., c_n\}$. Then the best (e.g. most desirable, most important) and the worst (e.g. least desirable, least important) criteria are determined. Two vector named as best-to-others (BO) and others-to-worst (OW) vector are determined where BO and OW vector are formulated as $A_B = \{a_{B1}, a_{B1}, ..., a_{Bn}\}$ and $A_W = \{a_{1W}, a_{1W}, ..., a_{nW}\}^T$, respectively. Finally, the optimal weights (w_1^*, w_2^*, ..., w_n^*) are obtained using Eq. (2).

$$\text{Min } \varphi \tag{2}$$

s.t.:

$$\left|\omega_B - a_{Bj}\omega_j\right| \le \varphi \quad \text{for all } j$$

$$\left|\omega_j - a_{jW}\omega_W\right| \le \varphi \quad \text{for all } j$$

$$\sum_j \omega_j = 1, \quad \omega_j \ge 0 \quad \text{for all } j$$

2.3. VIKOR technique

VIKOR was first proposed by Opricovic [18, 19] which is utilized to handles the situation of conflicting criteria in decision-making and there might be no solution satisfying all criteria simultaneously. The core feature of VIKOR is to evaluate a set of alternatives and propose a ranking that resolves disagreements by providing compromised solutions based on its closeness to the ideal solution.

The VIKOR procedures is composed of several steps. First, the value of f_{ij}, which represents the value of criterion *i* (*i* =1, 2, 3,…, *n*) for each of alternative *j* (*j* = 1, 2, 3, ..., *m*) are determined. For cost typed criteria, the value of $f_i^+ = \min_j f_{ij}$ and $f_i^- = \max_j f_{ij}$ are then selected. After that, ranking measures are calculated using two formulations, i.e.,

$$S_j = \sum_{i=1}^{n} \frac{\omega_i(|f_i^+ - f_{ij}|)}{f_i^+ - f_i^-} \tag{3}$$

$$R_j = \max_i \left(\frac{(|f_i^+ - f_{ij}|)}{f_i^+ - f_i^-}\right) \tag{4}$$

where S_j and R_j represents the distance of j-th alternative from positive ideal solution and from negative ideal solution, respectively, and ω_i denotes criteria weight calculated from measuring criteria relative importance. Next, the value of Q_j are computed where:

$$Q_j = \frac{(S_j - S^+)}{S^- - S^+} + \frac{(1-v)(R_j - R^+)}{R^- - R^+} \tag{5}$$

where $S^+ = \min_j S_j$, $S^- = \max_j S_j$, $R^+ = \min_j R_j$, $R^- = \max_j R_j$, and *v* indicates the weight where the value is assumed to be 0.5 [20]. Finally, ranking of alternatives is obtained by sorting *S*, *R*, and *Q* in increasing order. Assuming $a^{(1)}$ and $a^{(2)}$ are the first and second ranked alternative in Q list, respectively, then alternative $a^{(1)}$ is the best compromise solution if the two conditions are satisfied: "Acceptable advantage" and "Acceptable stability in decision-making". First condition satisfies $Q(a^{(2)}) - Q(a^{(1)}) \ge DQ$ where $DQ = 1/(m-1)$, and second condition requires that $a^{(1)}$ should also be ranked first according to *S* and/or *R*. If one of the above conditions is not satisfied then a set of compromised solutions are obtained where the following rules are applied: 1) If only the condition 2 is not satisfied, $a^{(1)}$ and $a^{(2)}$ are both the compromised solutions; 2) If the condition 1 is not satisfied, $a^{(1)}$, $a^{(2)}$,..., $a^{(n)}$ becomes compromised solutions where $a^{(n)}$ is determined by the relation $Q(a^{(n)}) - Q(a^{(1)}) < DQ$ for maximum *n* (the positions of these alternatives are "in closeness").

3. Industrial case problem

3.1. Result

To illustrate the usefulness of our proposed methodology, a case study was carried out in a crumb rubber industry named as XYZ Co. here (due to confidentiality), located in Padang city, Indonesia. The raw material (raw rubber) is mostly supplied by rubber farmers, classified as smallholders localized in West Sumatera and other surrounding regions. In particular, the supply system of XYZ Co. involves suppliers characterized by limited capacity, uncertain delivery lead time and low raw rubber quality. To anticipate

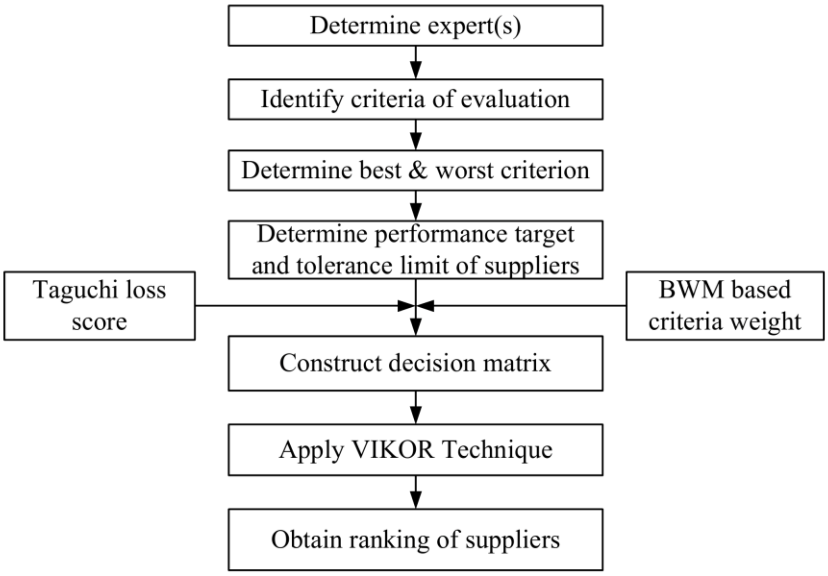


Figure 1. The proposed approach

material shortages, the XYZ Co. adopts a daily-basis supply from suppliers with fixed predetermined price. From current 18 suppliers only five of them constantly provides regular supply to which the proposed approach is applied. The proposed methodology is depicted in Figure 1.

Step 1: Determine the candidate of expert for decision making. To conduct evaluation process, individual opinion by the Chief, as a senior DM, and group opinion by a panel consisting of supporting experts within the company, including the Chief himself, was adopted depending on data requirement. These experts include purchasing, production, quality control, and warehousing supervisor.

Step 2: Identify criteria of evaluation. After presenting some criteria gathered from literature review to the panel, 5 (five) criteria were finally chosen as the most relevant criteria, i.e., quality (C1), quantity (C2), continuity (C3), responsiveness (C4), and reputation (C5).

Step 3: Compute the loss score of supplier using TLF. Due to criteria nature, a larger-is-better type loss function was chosen to specify the performance characteristic of all suppliers. Performance target values and tolerances limit (T) of suppliers are then determined through panel discussion (Table 1).

Eight-month performance data of suppliers are gathered for the first three criteria. A qualitative assessment for the last two criteria is performed based on aggregate measures for the entire periods as period-by-period performance does not fluctuate significantly. Due to restricted number of pages, the

Table 1. Target Quality characteristics of criteria

Criteria	Target value	(T, %)	Loss at T (%)	k	Loss Function
C1	100%	46	100	0.212	$L(x)$ = 0.212 MSD
C2	The greatest	30% lower	100	0.090	$L(x)$ = 0.090 MSD
C3	The most frequent	20% lower	100	0.040	$L(x)$ = 0.040 MSD
C4	Score of 100	70	100	4900	$L(x) = 4900\ (1/x^2)$
C5	Score of 100	75	100	5625	$L(x) = 5625\ (1/x^2)$

Table 2. Decision matrix of loss scores

Supplier n	C1	C2	C3	C4	C5
S1	66.59	292.43	10.07	60.49	114.80
S2	61.33	17.02	5.30	100.00	87.89
S3	66.02	2052.68	89.57	87.11	100.00
S4	58.54	1414.49	54.16	76.56	69.44
S5	55.06	91285.71	907.80	87.11	100.00

Table 3. Pairwise comparison of criteria

Best criterion:	The DMs	C1	C2	C3	C4	C5
C1	The chief	1	2	7	4	5
	Pc. M	1	2	5	4	4
	Pd. M	1	2	5	4	2
	Qc. M	1	4	7	5	2
	Wh. M	1	2	5	4	2

Worst criterion: C3	The DMs				
	The chief	Pc. M	Pd. M	Qc. M	Wh. M
C1	7	5	5	7	5
C2	5	4	4	4	4
C3	1	1	1	1	1
C4	3	2	2	2	2
C5	2	2	4	5	4

Pc. M = Purchasing Manager; Pd. M = Production Manager; Qc. M = QC Manager; Wh. M = Warehousing Manager

performance data are not presented in this paper. The value of k and loss functions $L(x)$ are formulated using the data on Table 1. For example, k for quantity criterion is calculated as k = 100% × (30%)^2 = 0.090. Since eight performance data are collected, mean squared deviation (MSD) of data is used to formulate the loss function which is $L(x)$ = 0.090 × MSD.

Step 4: Obtain the weight of criteria using fuzzy-BWM. Best and worst criterion were selected by the panel through mutual consensus, and after that all preference rating used for BO and OW vectors are determined individually by each panel member (Table 3). By the above process, C1 and C3 are chosen as the best and the worst criterion, respectively. Using Eq. (2), the criteria weights along with the values of φ are calculated for five panel members, and by averaging these value the mean weights are obtained (Table 4). Finally, consistency check was carried out for all φ. For example, from comparison performed by the Chief, φ is 0.6834 whose value of $a_{BW} = a_{13}$= 7 with the consistency index of 3.73 (see [18] for details). So, consistency ratio is become 0.6834 / 3.73 = 0.1832, which indicates a good consistency because this value is close to zero.

Step 5: Obtain the rank of supplier using VIKOR. The decision matrix and criteria weights are used to rank suppliers based on VIKOR technique. Noted that the loss scores with respect to each criterion

Table 4. Weights of criteria

Criteria	Mean weights	Individual weights				
		The chief	Pc. M	Pd. M	Qc. M	Wh. M
C1	0,4129	0,4439	0,4362	0,3619	0,4610	0,3619
C2	0,2263	0,2686	0,2545	0,2348	0,1390	0,2348
C3	0,0654	0,0578	0,0767	0,0663	0,0600	0,0663
C4	0,1102	0,1338	0,1315	0,1022	0,0811	0,1022
C5	0,1851	0,0958	0,1010	0,2348	0,2590	0,2348
φ		0,6834	0,6834	0,4586	0,6834	0,4586

Pc. M = Purchasing Manager; Pd. M = Production Manager; Qc. M = QC Manager; Wh. M = Warehousing Manager

Table 5. The value of S, R and Q of suppliers

Supplier n	S	S-rank	R	R-rank	Q	Q- rank
S1	0,8423	4	0,4129	5	0,9255	4
S2	0,4522	1	0,2437	3	0,0531	2
S3	0,9106	5	0,3959	4	0,9550	5
S4	0,4833	2	0,2236	1	0,0338	1
S5	0,5201	3	0,2263	2	0,0811	3
	S^* = 0.4522		R^* = 0.2236		j = 5	
	S^- = 0.9106		R^- = 0.4192		DQ = 0.25	

uses different scale, making it less comparable with each other. Therefore, those values are first normalized by a linear scale transformation. The normalized value, r_{ij}, is computed as $r_{ij} = x_j^{\min} / x_{ij}$, where x_{ij} is the the loss score of supplier i for criteria j and $x_j^{\min} = \min_i x_j$. After identifying a maximum and minimum values of r_{ij}, the value of S_i, R_i and Q_i are calculated using Eq. (3)-(5) where v is set to 0.5. Table 5 shows that the supplier with the lowest and the second lowest Q are identified as supplier 4 (S4) and supplier 2 (S2), respectively. Examining the condition of VIKOR, the first conditions of "Acceptable advantage" is not satisfied since the value $Q(S_2) - Q(S_4) = 0.0193$, which is less than $DQ = 1/(5\text{-}1) = 0.25$. However, for the second condition it is found that supplier 4 is obtain the minimum value of R, hence, it is a stable alternative which satisfies the second condition. Therefore, a set of compromised ranking is obtained as S4-S2-S5 >S1>S3 where S4, S2 and S5 are top suppliers, followed by S1 and S3 as the second and the third ranked suppliers, respectively.

3.2. Implications

The proposed approach provides some practical implications for decision makers. This research adopts the value of quality loss by Taguchi as a loss score of suppliers in performance evaluation. This common value provides understandable language in decision making, and utilizing this value to evaluate suppliers makes evaluation process will be much easier and meaningful. More specifically, Taguchi allows decision makers to set performance target values and tolerance limit that is very important in the context of supplier evaluation and selection problem since each enterprise with different organizational goals might use different performance criteria and measurement with different acceptable tolerance limits. Thus, this feature enables decision makers to perform the most precise and comprehensive supplier evaluation with respect to their specific goals.

Using BWM brings a significant benefit for decision making process because aside of improving computational load due to its compact yet efficient steps, this method is capable of producing good consistency rate in the presence of conflicting criteria. By incorporating the BWM's results into VIKOR technique, the DM are able to obtain a compromised supplier ranking lists, providing the closest solution to the ideal. Hence, utilizing it in the proposed approach increases the efficiency of the decision making process.

4. Conclusion

This research proposed a comprehensive approach of multi-criteria decision making that integrates Taguchi loss function (TLF), fuzzy BWM and VIKOR in performance evaluation of suppliers. The merit of using the proposed methodology is that it enables the DM to take the benefit from each method's individual advantage simultaneously in making an appropriate decision. The use of the proposed approach was applied in the industrial case to examine its feasibility in evaluation and selecting the best supplier of crumb rubber industry. Based on the case study, it is convincingly useful for solving an empirical case problem with actual data and feedback from experts both in either single or group opinion.

References

[1] Pazhani S, Ventura J A and Mendoza A 2015 *Appl. Math. Model* **40** 612-34
[2] Xia W and Wu Z 2007 *Omega* **35** 494-504
[3] Glock C H, Grosse E H and Ries J M 2017 *Int'l. J. Prod. Econ* Article in Press.
[4] Jain V, Sangaiah A K, Sakhuja S, Thoduka N and Aggarwal R 2016 *Neur. Comput. & Appl.* 1-10
[5] Pitchipoo P, Venkumar P and Rajakarunakaran S 2013 *J. Ind. Eng. Int'l.* **9** 23 1-15
[6] Yadav V and Sharma M 2015 *J. Enterp. Inform. Manag.* **28** 2 218-42
[7] Liu P and Zhang X 2011 *Int'l. J. Prod. Res.* **49** 3 637–46
[8] Hsu C W, Kuo R J and Chiou CY 2014 *Int'l. J. Env. Sci. Tech.* **11** 3 775–84
[9] Chang B, Chang C and Wu C 2011 *Exp. Syst. App.* **38** 3 1850–58
[10] Parkouhi S V and Ghadikolaei A S 2017 *J. Clean. Prod.* **161** 431-51
[11] Chen Y-J 2011 *Inform. Sci.* **181** 9 1651-70
[12] Adali E, Işık A and Kundakcı K 2016 *Uncert. Supp. Chain Manag.* **4** 3 183-94

[13] Kuo T C, Hsu C W and Li J Y 2015 *Sustainability* **7** 2 1661-1689
[14] Gupta H and Barua M K 2017 *J. Clean. Prod.* **152** 242-58
[15] Zeydan M, Çolpan C and Çobanoğlu C 2011 *Exp. Syst. App.* **38** 2741-51
[16] Büyüközkan G and Çifçi G 2012 *Exp. Syst. App*. **39** 3 3000-11
[17] Rezaei J, Fahim P B M and Tavasszy L 2014 *Exp. Syst. App.* **41**18 8165-79
[18] Opricovic S 1998 *Multicriteria Optimization of Civil Engineering Systems* (Belgrade: Faculty of Civil Engineering) **2** 1 5-21
[19] Opricovic S and Tzeng G H 2007 *Eur. J. Oper. Res.* **178** 2 514-29
[20] Kackar R N 1985 J. Qual. Tech. **17** 4 176–88

APCOMS-iMEC 2017

4th Asia-Pacific Conference on Manufacturing Systems
3rd International Manufacturing Engineering Conference

"Taking The Factories to The Next Level"

Certificate of Participation

This certificate is presented to

Dicky Fatrias

in recognition of your participation in the Conference

December 7th - 8th, 2017

Conference Chair,

Mohammad Mi'raj Isnaini, ST., MT., Ph.D.