OmniaScience

Journal of Industrial Engineering and Management
JIEM, 2018 – 11(4): 680-696 – Online ISSN: 2013-0953 – Print ISSN: 2013-8423
https://doi.org/10.3926/jiem.2203

A Literature Review of Design of Criteria for Supplier Selection

Agus Ristono, Pratikto, Purnomo Budi Santoso, Ishardita Pambudi Tama

Brawijaya University (Indonesia)

agus.ristono@upnyk.ac.id, pratiktoprawoto@yahoo.com, pbso3@ub.ac.id, kangdith@ub.ac.id

Received: December 2016
Accepted: July 2018

Abstract:

Purpose: This paper proposes a new model for further research on how to select criteria in supplier selection, through a literature review and analysis of the advantages and disadvantages of previously used methods.

Design/methodology/approach: The methods used to select criteria in supplier selection were extracted from various online academic databases. The weaknesses and advantages of these methods were then analyzed. Based on these findings, several opportunities for improvement are proposed for further research. Finally, criteria design methods for the selection of suppliers are proposed using statistical multi-criteria decision making (MCDM) methods.

Findings: Direction and guidance for subsequent research to select the criteria used in supplier selection, based on the advantages and disadvantages of the decision methods used.

Research limitations/implications: Limitations of this study are that it is focused on the methods of criteria design in the supplier selection.

Practical implications: This study can provide a research direction on the design of criteria for supplier selection.

Social implications: This study provides ongoing guidance and avenues for further research.

Originality/value: New ideas for working out the developmental strategy for criteria selection are provided by statistical-MCDM methods in the supplier selection.

Keywords: criteria selection, supplier selection, criteria, method

To cite this article:

Ristono, A., Pratikto, Budi Santoso, P., & Pambudi Tama, I. (2018). A literature review of design of criteria for supplier selection. *Journal of Industrial Engineering and Management*, 11(4), 680-696.
https://doi.org/10.3926/jiem.2203

1. Introduction

The goal of supplier selection processes is to get the best supplier for a particular situation. Which supplier is "best" depends on several factors, all of which must be assessed and weighed. Generally, the supplier selection process involves three basic stages. The first stage is identification and selection of criteria that will be considered in the selection of suppliers. The second stage is the determination of methods for the assessment of suppliers based on these criteria. The last stage is the selection of suppliers based on the assessment results. Most of the research papers in the field of supplier selection, although they do explain how their decision criteria were determined, most always focus on the second stage in the process of selecting suppliers. Therefore, there are also many literature reviews related to supplier selection methods that also focus on the second stage as well.

Ho, Xu and Dey (2010) review in detail the use of multi-criteria decision making (MCDM) in the selection of suppliers, based on research articles from 2000 to 2008. Masi, Micheli and Cagno (2013) analyzed supplier selection techniques used up to 2013, based on two dimensions: the level of difficulty in managing the purchase and the impact of the purchase on the project. Chai, Liu and Ngai (2013) review the literature on the application of methods of decision making in the systematic selection of suppliers, using articles from 2008 up to 2012. Igarashi, de Boer and Fet (2013) review articles on the selection of green suppliers, ranging from 1991 to 2011, categorizing them either as analytical research or empirical research. Govindan, Rajendran, Sarkis and Murugesan (2015) reviewed published research of green supplier selection from 1997 to 2011.

This paper analyses the gaps in the current literature and then to identify improvements for future directions in the green supplier selection process.

Figure 1. Focus of this survey in the process of supplier selection

The reviews discussed above only focus on discussing the methods used in the selection of suppliers. There is a need for a review of supplier selection criteria and methods relating to the determination of these criteria, as these are vitally important to the success of the later steps and overall outcome. As discussed in this review, we comprehensively collected the literature associated with the keywords "selection of supplier criteria" and "selection of vendor criteria" in the academic databases. This research then tried to answer the following three questions: (1) What are methods that are often used in selection of supplier criteria? (2) What are future research opportunities in selection of supplier criteria? And (3) What are framework model which appropriate in the selection of supplier criteria?

The paper is organized as follows: Section 2 presents the research methodology, describing the methods for selecting the literature used. In Section 3, we analyze methods used in selection of supplier criteria. Section 4 gives advice for the future. We conclude this paper in Section 5.

2. Steps of this Research

The steps of this literature review are depicted in Figure 2. The goal of this research was the investigation the application of supplier criteria selection in the current research. The first step was online searching from academic databases including Elsevier (http://sciencedirect.com), Emerald (http://emeraldinsight.com), Springer-Link Journal (http://link.springer.com), Francis & Taylor (http://tandfonline.com), Inderscience (http://inderscience.com), Sage publishing (http://uk.sagepub.com), World Scientific (http://worldscientific.com), and open access database (Hindawi (http://hindawi.com), Management Production and Engineering Review (http://mper.org/mper/), Journal of Industrial Engineering and Management (http://jiem.org), International Journal for Quality Research (http://ijqr.net)). The keywords for online searching were "selection of supplier criteria" and "selection of vendor criteria."

The second step was article selection. The selected articles were specialized research on the selection of supplier criteria. Research on supplier selection that did not specifically address the criteria selection method were not included. Further, only articles that had been published between 2008 and 2018 were adopted. This study covers only international journal articles, so conference articles, master and doctoral dissertations, textbooks, unpublished articles, and notes were not included in this review.

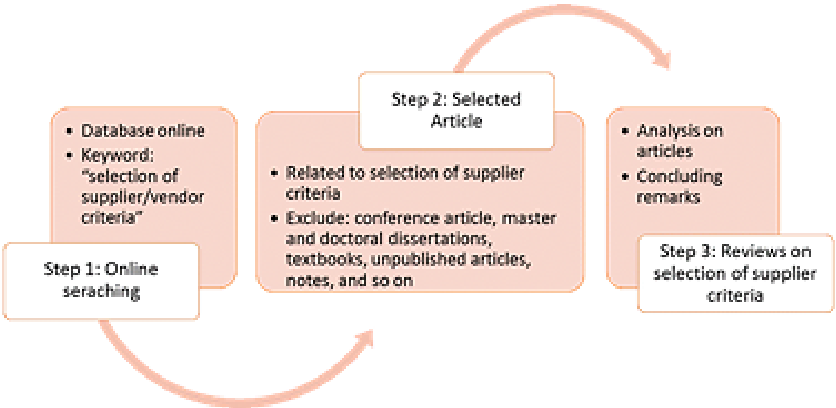

Figure 2. Steps of this research

The final stage was to analyze the selected articles. The methods used and how the method works were extracted from each article (see Section 3), to analyze the weaknesses and advantages of each method used. Based on this information, new methods can be constructed that can overcome the weakness of one or more methods by taking advantage of the strengths of other methods (see Section 4). Thus, the next opportunities for research can be predicted.

3. Reviews Categories of Criteria Selection

A total of 34 international journal articles published from 2008 to 2018 were included in our sample. After the analysis of methodological decisions of all the articles collected, the distribution of the methods used in selection criteria for supplier selection is shown in Figure 3. There were four methods are the first rank: Analytical Hierarchy Process (AHP), Intepretative Structural Model (ISM), Decision Making Trial And Evaluation Laboratory (DEMATEL), Principal Component Analysis (PCA)/Analysis Factor, then followed by Analysis of variance (ANOVA).

Based on our investigation, we summarized the seventeen methods that have been used for selection of criteria. We classify these methods into four categories, namely: Delphi (Section 3.1), Statistical (Section 3.2), multi criteria decision making (MCDM) (Section 3.3), and mixed methods (Section 3.4).

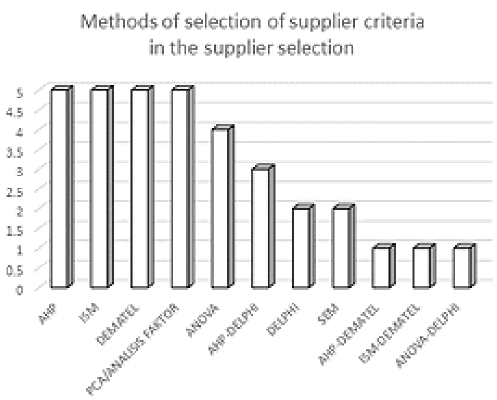

Figure 3. Methods of selection of supplier criteria

3.1. Overview of Selection Criteria Using Delphi

The Delphi evaluation method uses a theoretical decision approach. Theoretical decisions approaches use descriptive methods to generate valid and accountable information about policy outcomes explicitly assessed by various policy actors. This method allows experts to systematically approve decisions affecting complex problems (Handayani, Cakravastia, Diawati & Bahagia, 2012). The steps of the Delphi method can be seen in Figure 4. In the first step, the selected panelist must be an expert related to the object under investigation. Experts who give opinions should not know each other.

The questionnaire in second step is usually compiled in tabulation format (matrix). In Questionnaire I (Table 1), a transformation statement from the criteria and indicators was prepared, then verified and validated by the relevant experts. Questionnaire I is designed to be able to bring up or develop an individual response to a problem and review the opinions of some experts or experts about the problems that have been established. Questionnaire I is a primary data-gathering tool that is compiled based on required and relevant variables and parameters in accordance with supplier selection.

In the third step, what criteria are considered to represent all the variables that affect the selection of suppliers are determined. The objective of the third step is to gather input and opinions from some experts. Then, those statements are transformed into questions. The statement is used as a guide in making questionnaire II (Step 4). Questionnaire II (Table 2) is used as a data collection instrument distributed to respondents who can represent the population related to these criteria. The last step generates a consensus for an opinion from a group of experts or panelists (Handayani et al., 2012). They will keep their unanimity between them. This step is used to solve the lack of conventional action or committee activities, such as caused by difficultly meeting.

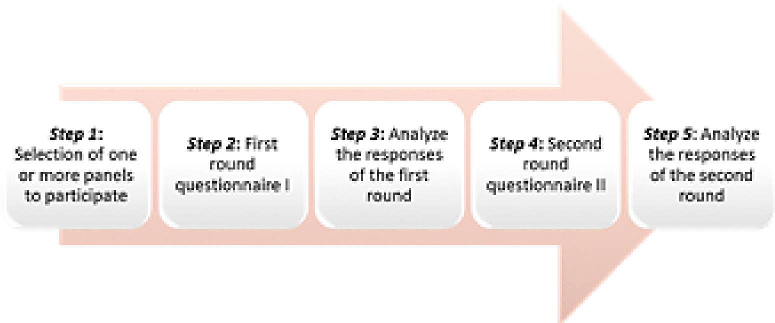

Figure 4. The steps of Delphi

No	Variables/Indicators that influence on supplier selection (provide benefits to the company)	1	2	3	4	5	Comments / responses
1	Variables V_1						
2	Variables V_2						
⋮	⋮						
m	Variables V_m						

Table 1. Example of Questioner I

No	Criteria and sub-criteria	Level of influence on supplier selection				
		1	2	3	4	5
1	Criteria C_1					
2	Criteria C_2					
⋮	⋮					
n	Criteria C_n					

Table 2. Example of Questioner II

Banaeian, Nielsen, Mobli and Omid (2014), give two questions to each Delphi panelist. The first question is “based on a collection of criteria, describe subcriteria that are important in supplier selection.” The second question is “give to each subcriteria, the value between 1 (not important) to 9 (very important).” They then give the Delphi score to each criterion using equation (1). Their approach was similar to Kar and Peni (2014), but the latter authors calculated the Delphi score on each criterion using a geometric mean.

3.2. Overview of Selection Criteria Based on Statistical Method

3.2.1. DEMATEL

The steps of DEMATEL are shown in Figure 5. The first step is to determine the relationship that occurs between supplier selection criteria. Data input in this step is a questionnaire that has been filled in by the previous respondents. Then, this matrix is normalized in the second step. The purpose of this step is to find a direct relationship matrix by normalizing the basic matrix of the relationship. All normalized matrices of each questionnaire result are combined (Step 3). Step 4 is called a causal diagram, because it demonstrates a cause and effect relationship. The goal of this step is to find and analyze the dominant criteria of supplier selection system. The last step is used to determine the relationships that occur between the criteria which used. In addition, the DEMATEL method uses matrices and diagrams to visualize causal relationships and analysis of the predominant criteria on a supplier selection problem (Orji & Wei, 2014).

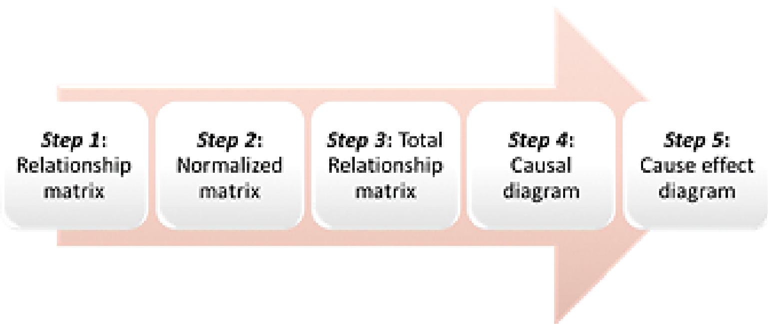

Figure 5. The steps of DEMATEL

Chang, Chang and Wu (2011) proposed DEMATEL to evaluate the effect of each of the criteria of a set of decision-making criteria. Their study used ten criteria, interviewing several experts in the purchasing department of the electronics industry in Taiwan. Questionnaires were sent to seventeen professional purchasing personnel in the industry. Respondents were asked to compare the importance of each criterion using a score of 1, 2, 3 and 4 to represent the level of significance. Scores of 1, 2, 3, and 4 represent “not important,” “low interest,” “high importance,” and “very high interest,” respectively.

The second part is the pairwise comparisons to evaluate the influence of each score, where a score of 0, 1, 2, 3 and 4 represents “no influence,” “low impact,” “influence normal,” “high leverage,” and “very high impact,” respectively. Then the average value is calculated. The results showed the four most important criteria with importance greater than or equal to 3.5. They analyzed the level of the central roles and relationships and created strategy maps and a causal diagram. Their results found that the stable delivery of goods was most influential and had the strongest connection to other criteria. A similar study was conducted by Tsai, Saito, Lin and Chen (2015) and Tsai, Wei, Chen, Xu, Du and Lee (2016), but their average importance level seen was 5.6. In addition, they focused on green criteria.

Mavi and Shahabi (2015) used DEMATEL to evaluate the effect of effective factors in the selection of suppliers in the manufacturing industry. Through data input from twenty experts from academia and practitioners, three main criteria were obtained with 15 sub-criteria. Abdel-Basset, Manogaran, Gamal and Smarandache (2018) used a modified DEMATEL, where the stages were: (1) objective identification, (2) the opinions of each expert are shown in pairwise comparison matrix, (3) integrating the opinions of all experts in one matrix, (4) creating direct relation matrix, (5) normalizing the direct relation matrix, (6) attaining the total relation matrix, (7) obtaining the sum of rows and columns, and (8) visualize it in a cause and effect diagram.

3.2.2. Analysis of Variance (ANOVA)

ANOVA can be used to analyze a number of criteria with the same amount of data in each group or with different amounts of data. ANOVA require research data to be grouped based on certain factors. The use of "variance" is in accordance with the basic principle of sample differences: differences in criteria are viewed via their variability. A good measure of variability is the variance or standard deviation. Data can be obtained from the questionnaire survey, where questionnaires are distributed to experts or decision makers.

Kim and Boo (2010) used questionnaires to obtain supplier criteria. Then, they measured the importance level on a five-point Likert scale, ranging from 1 (not important at all) to 5 (very important). The last stage used by the authors was a paired-sample t test. This test is used to assess the difference between supplier selection decisions with suppliers. The result was that there is a relationship between the "supplier's technical capability" and the criteria of "ability to meet specified delivery " ($p<0.05$). Like-wise for the criteria "number of past business suppliers" ($p<0.01$). However, the other 11 criteria are not statistically significant ($p> 0.05$), regardless of their positive or negative means.

Eshtehardian, Ghodousi and Bejanpour (2013) used ratings that on a 1–9 scale. Consistency of the answers were tested using Cronbach's α method. Data from the questionnaires were evaluated using Student's t-test. A total of 18 criteria were selected as criteria in the selection of suppliers, and five criteria were discarded. Voss (2013)used a t-test to assess the significant differences in interest scores of a criterion between groups of respondents. Furthermore, significant differences in group preferences were assessed for different levels of factors. So, one criterion will be used if it had an insignificant degree of intergroup differences. Olorunniwo and Jolayemi (2014)collected several criteria from the literature and in-depth interviews with senior purchasing managers in 15 companies. These criteria were assessed by two groups, each group consisting of 37 respondents. One group assessed the criteria for the manufacturing industry, while the other group assessed the criteria for non-manufacturing industries. The t-test results sshowed a significant difference between the criteria values of both groups.

3.2.3. Principal Component Analysis/Factor Analysis

The purpose of principal component analysis (PCA) is to reduce the existing criteria to a smaller number without losing the information contained in the original data (Feng, Li & Gong, 2014). Using a PCA, criteria that were previously n criteria will be reduced to k criteria (principal component) with a number of k less than n and using only k principal components will yield the same value using n criteria. The steps of PCA, simplified, are shown in Figure 6.

In the first step, the participants were asked to evaluate various criteria. Then, factorability of this data was tested with Bartlett's test of sphericity. Bartlett's test of sphericity is used to determine whether there is a significant correlation between criteria (Xu, Zhang, & Ma, 2013). The next step is sampling accuracy, which measured using the Kaiser–Meyer–Olkin (KMO) test. The KMO test measures sampling adequacy by comparing the magnitude of the observed correlation with partial correlation (Xu, Zhang et al., 2013). A reliability test is performed by using Cronbach's Alpha. The lowest value of Cronbach's Alpha is 0.7, which is generally agreed upon (Guo, Guan & Song, 2012).

In the third step, there are two ways used in determining the relationship between criteria, i.e., by calculating the correlation value (correlation matrix) between the criteria and by calculating the covariance (covariance matrix) of all criteria. In this analysis, the correlation of each criteria and the form in a correlation matrix is calculated. From the correlation matrix is then analyzed in Step 4, by looking at the eigenvalues that exist in each criterion. The new variable (principal component) formed is based on more than one eigenvalue (Xu, Liang & Li, 2013). The last step is to create new variable. To determine what criteria are included in this new variable and the criteria that really affect the selection of suppliers, a factor rotation (transformation) is made using the varimax factor rotation methodology (Xu, Liang et al., 2013).

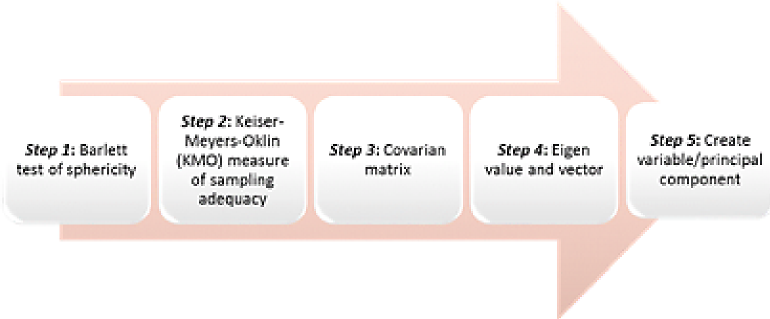

Figure 6. The steps of PCA

Lam, Tao and Lam (2010) used PCA to reduce the number of criteria and eliminate the multi collinearity among them for supplier selection. Imeri et al. (2015) and Chen, Hsieh and Wee (2014) specified what criteria were used in selection of suppliers using PCA: Imeri, Shahzad, Takala, Liu, Sillanpaa and Ali (2015) investigated 80 small- to medium-sized companies (SMEs) in Greece; Chen, Hsieh et al. (2014) nvestigated the surface mount technology (SMT) industry in Taiwan. In Imeri et al. (2015), their exploratory research showed their lowest value of Cronbach's Alpha was 0.6, which was suitable in their study. Then, one-way ANOVA was used to test for differences between performance of criteria and industry types. However, Chen, Hsieh et al. (2014) used 0.3 as their lowest value for Cronbach's Alpha.

A similar study was also conducted by Mohanty and Gohan (2011), but for the Indian manufacturing industry and secondary sourch information from previous research. El Mokadem (2017) grouped the selection criteria of suppliers into three groups. The first group was the lean criteria, the second group agile criteria and the third group general criteria. Thus, this study limited the number of extracted factors to only three. Varimax rotated analysis showed that three extracted factors explained 61.06% of the overall variance. The KMO value was 0.644, indicating no correlation between groups. In other words, grouping criteria into three groups is considered valid. In addition, Bartlett's Test of Spehericity results indicated that there is a correlation between criteria within that group, meaning that grouping the criteria is correct because the criteria have correlation with each other.

3.2.4. Interpretive Structural Modeling

The ISM method helps to establish relationships between criteria. ISM advises researchers to use expert opinions based on various management techniques such as brainstorming in developing contextual relationships between criteria (Gupta & Walton, 2016). For this purpose, researchers should consult with industry experts and academics in identifying contextual relationships between criteria. The steps of ISM can be explained as in Figure 7.

Construction of the Structural Self-Interaction Matrix (SSIM) is the first stage in the ISM method. Input data for SSIM are obtained from questionnaires and brainstorming with respondents to obtain the relationship between factors, namely relationships that affect each other. The expert group decides on whether and how the linkage between these criteria. SSIM is compiled based on expert opinion results. The questionnaire results in the form of symbols to indicate the direction of the relationship between two criteria, i.e., *i* and *j*. The symbols are *V* (criterion *i* influences criterion *j*), *A* (criterion *i* influenced criteria *j*), *X* (criterion *i* and *j* influence each other), or *O* (criteria *i* and *j* do not affect each other)(Gupta & Walton, 2016).

In the second stage, the SSIM is converted to an initial reachability matrix by substituting four symbols (*V*, *A*, *X*, or O) in the SSIM to 1 or 0 in the reachability matrix (Kumar, Gorane & Kant, 2015). If the symbol on the SSIM is *V*, then the entry (*i, j*) is 1 and the entries (*j, i*) are 0 on the reachability matrix. If the symbol on the SSIM is *A*, then the entry (*i, j*) is 0 and the entry (*j, i*) is 1 in the reachability matrix. If the symbol on the SSIM is *X*, then the entry (*i, j*) is 1 and the entry (*j, i*) is 1 in the reachability matrix. If the symbol on the SSIM is *O*, then the entry (*i, j*) is 0 and the entry (*j, i*) is 0 in the reachability matrix. Using the concept of transitivity (when *A* corresponds to *B, B* corresponds to *C*, then *A* corresponds to *C*), the initial reachability matrix is changed to the final reachability matrix (Kumar et al., 2015). In the final table, the reachability matrix will be used for the next stage of MICMAC analysis.

In the third step, partitions of the level reachability set, antecedent set, and intersection set of each criterias are established. Criteria that have an intersection set and the same reachability set are placed in level 1 of the ISM hierarchy. After level 1 is identified, the criteria that were selected are eliminated and then continued by the next iteration. In the next step, a conical matrix is made from the reachability matrix by arranging the order of criteria based on its level. The top of level criteria is placed at the top of the ISM model, the second-level criteria are placed in the second position of the ISM model, and so on until the lowest-level criteria lie at the bottom of the ISM model.

A Digraph is a structural model created from a conical matrix. Models are made using nodes. Each node is connected by a line. The Digraph is transformed into an ISM model by replacing the node with the criteria. The arrow direction indicates the relationship between the criteria. The ISM model is used to show the relationship between criteria in the form of lines and nodes. The first-level criteria is placed at the top of the ISM model, the second-level criteria is placed in the second position of the ISM model, and so on up to the lowest-level criteria.

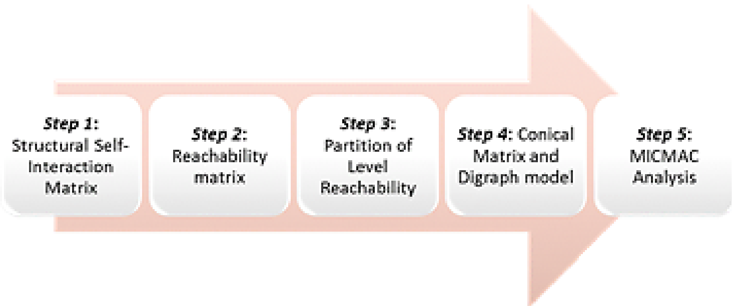

Figure 7. The steps of ISM

The last step is MICMAC Analysis (Matrice d'Impacts croises-multiplication appliqúe an classment). This step aims to analyze driving power and dependence power of driving criterias. MICMAC Analysis is a verification of the ISM model. In MICMAC Analysis, criteria are classified into four categories (Kumar et al., 2015; Gupta & Walton, 2016): Autonomous criteria (Quadrant I), (2) Dependent barrier criteria (Quadrant II), (3) Linkage criteria (Quadrant III), and (4) Independent criteria (Quadrant IV). Autonomous criteria are criteria that have weak driving power and weak dependency power. The barrier criteria in quadrant 1 do not have a large effect on the system. There are no criteria in this category. Dependent barriers are criteria that has a weak driving power and strong dependency power. Linkage criteria are criteria that have strong driving power and strong dependency power. Independent criteria are criteria that have strong driving power and weak dependency power.

Parthiban, Zubar and Garge (2012), Chen, Yeh and Huang (2014), and Girubha, Vinodh & Vimal (2016) used ISM to find linkages between criteria and weights to each criterion. The first step in this research was to identify the criteria considered in the selection of suppliers. Identification of criteria was done through discussions with experts in the automotive parts manufacturing industry (Parthiban et al., 2012) and the 3C industry Taiwan (Chen, Yeh et al., 2014). For studying the interaction between those criterias and prioritizing them, Parthiban et al. (2012) used ISM technique. However, the study of Chen, Yeh et al. (2014) and Girubha et al. (2016) proposed the Analytical Network Process (ANP) for the weighting. Kumar et al. (2015) used ISM with input data from an expert group of practitioners and academics to select criteria in general supplier selection. The same research was also done by Gupta and Walton (2016), but only applies in the Third-party logistics (3PL) provider.

3.2.5. Structural Equation Modeling

Structural Equation Modeling (SEM) is capable to determine the level of relationship between criteria, which is considered as a variable. SEM is a combination of factor analysis and regression analysis (Sukwadi & Yang, 2014). Figure 8 shows the steps of SEM. Those steps are (1) model specification, (2) data collection, (3) model identification, and (4) model testing (Panuwatwanich & Nguyen, 2017).

In the first step, a model is built using previously developed theories. This model can be made in two forms, namely: equations (mathematical equations) and diagrams (pictures). If the model is formed using a diagram, then the measurement model and the structural model need to be included. Before a model is tested, the model must be able to meet the assumptions of SEM. The third step is the model identification test. The purpose of this stage is to see whether the model can be further identified or not (whether there are degrees of freedom remaining).

Figure 8. The steps of SEM

The last step to be done is to test the model using a measurement model and a structural model. By using the measurement model, the relationship between the indicator criteria with the construct criteria can be obtained. While the structural measurement used to see the correlation between the construct criteria (Sukwadi & Yang, 2014). Punniyamoorthy, Mathiyalagan and Parthiban (2011) and Punniyamoorty, Mathiyalagan and Lakshmi (2012) collected some criteria from the literature and then discussed with experts in the field of election of the company's suppliers. The results of these discussions resulted in 10 criteria considered important in the selection of suppliers. They used SEM to determine the criteria considered in the selection of suppliers.

3.3. Overview of Criteria Selection Using MCDM

Multi-criteria decision making (MCDM) uhas also been used in criteria selection. Only AHP has been used in the criteria selection, such as Lin and Lin (2008), Xu, Kumar, Shankar, Kannan and Chen (2013), Felice, Deldoost and Faizollahi (2015), Patra and Dash (2015), and Mathiyazhagan, Sudhakar and Bhalotia (2018). The AHP steps are shown in a simplified form in Figure 9.

Step 1 is pairwise comparison. This matrix is contained the element of a_{ij}. This element is rating of comparison of criteria *i* and *j*. The a_{ij} value is equal to 1 if criteria *i* and criteria *j* are equally important. It's equal to 3 if criteria *i* is moderately more important than criteria *j*. It's equal to 5 if criteria *i* is strongly more important than criteria *j; 7* if criteria *i* is very strongly more important than criteria *j;* and 9 if criteria *i* is extremely more important than criteria *j*. Then, this matrix is normalized in the second step. As discussed in (Saaty, 1990)based on normalization matrix, the relative weight of criteria using equation (1) can be calculated; the next step is to develop matrix of eigen value and this matrix can be calculated using equation (2); Equation (3) is the last step. If the value of the consistency ratio (CR) is less then 0.1, the matrix of pairwise comparison is not consistent. Then, the matrix must be revised until CR value is less then 0.1.

$$W_i = \begin{bmatrix} W_1 \\ W_2 \\ \vdots \\ W_n \end{bmatrix} = \begin{bmatrix} \left[\dfrac{a_{11}}{\sum_{i=1}^{n} a_{i1}} + \dfrac{a_{12}}{\sum_{i=1}^{n} a_{i2}} + \ldots + \dfrac{a_{1n}}{\sum_{i=1}^{n} a_{in}} \right] \cdot \left(\dfrac{1}{n} \right) \\ \left[\dfrac{a_{21}}{\sum_{i=1}^{n} a_{i1}} + \dfrac{a_{22}}{\sum_{i=1}^{n} a_{i2}} + \ldots + \dfrac{a_{2n}}{\sum_{i=1}^{n} a_{in}} \right] \cdot \left(\dfrac{1}{n} \right) \\ \vdots \\ \left[\dfrac{a_{n1}}{\sum_{i=1}^{n} a_{i1}} + \dfrac{a_{n2}}{\sum_{i=1}^{n} a_{i2}} + \ldots + \dfrac{a_{nn}}{\sum_{i=1}^{n} a_{in}} \right] \cdot \left(\dfrac{1}{n} \right) \end{bmatrix} \quad (1)$$

$$\lambda_i = \begin{bmatrix} \lambda_1 \\ \lambda_2 \\ \vdots \\ \lambda_n \end{bmatrix} = \begin{bmatrix} \left(\frac{a_{11}}{W_1} + \frac{a_{12}}{W_2} + \ldots + \frac{a_{1n}}{W_n} \right) / W_1 \\ \left(\frac{a_{21}}{W_1} + \frac{a_{22}}{W_2} + \ldots + \frac{a_{2n}}{W_n} \right) / W_2 \\ \vdots \\ \left(\frac{a_{n1}}{W_1} + \frac{a_{n2}}{W_2} + \ldots + \frac{a_{nn}}{W_n} \right) / W_n \end{bmatrix} \tag{2}$$

$$CR = \frac{\left[\frac{\lambda_{\max} - n}{(n-1)} \right]}{RI} \tag{3}$$

Lin and Lin (2008) introduced two phases to select traditional criteria in the supplier selection. In the phase I, a questionnaire was distributed to experts. In the phase II, experts were asked about the relative importance of the different criteria. This step is the input for AHP. A similar method was used by Xu, Kumar et al. (2013); . however, they interviewed in the group of experts to produce one pair wise comparison result Xu, Kumar et al. (2013) focused on selection of criteria relating to corporate social responsibilities (CSR).

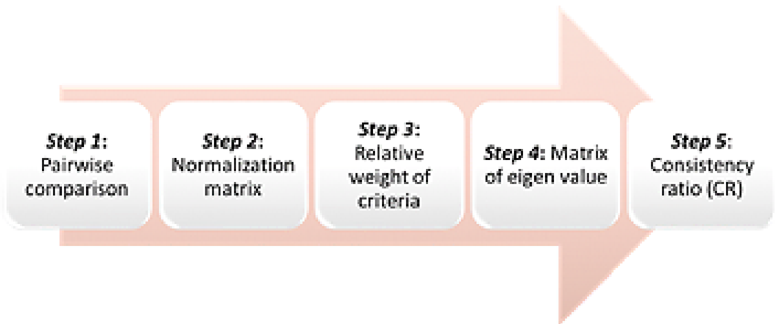

Figure 9. The steps of AHP

Felice et al. (2015) collected criteria from literature and rearranged them in the form of hierarchy, so as to form the main criteria and sub-criteria. The next step was to send it to the experts. Experts were asked to fill out the questionnaire in the form of matrix pairwise comparison of the main criteria and sub-criteria. This study processed those questionnaire data using AHP. The result was a sequence of main criteria and sub-criteria. Patra and Dash (2015) identified important criteria. The selection of these criteria was determined through a literature survey and discussions which held with experts during industry visits. The criteria and sub criteria are then weighted using AHP. Mathiyazhagan et al. (2018) defined green criteria based on expert judgment. Questionnaires were given to 15 car manufacturers to get their opinions. Collected data is processed using AHP to obtain green criteria ranking.

3.4. Overview of Criteria Selection Using Mixed Method

Several researchers have combined more than one type of method. Tsaur and Ling (2014) provided questionnaires to several experts twice, three months apart. They used a t-test to find out whether there was a difference or not about the criteria they choose to select supplier. The next step was to calculate the weight of criteria using AHP. The purpose of this step was to rank the selected criteria.

Several selection criterion studies have combined Delphi and AHP, such as Luzon and El-Sayegh (2016), Kar (2015), and Banaeian, Nielsen, Mobli and Omid (2015). Kar (2015) utilized a 'Delphi group' (expert group) to determine criteria that are appropriate to the iron-steel industry, then, prioritized each criterion using AHP. Banaeian et al. (2015) collected criteria from the literature and then selected the most popular. A Delphi group discussed those selected criteria and then scored the selected criteria. AHP was used to weight the selected criteria. Luzon and El-Sayegh (2016) submitted 23 criteria to experts to be assessed. Experts were asked to evaluate the importance of each criterion. Their assessment ranged from 5 to 1 (5 very important, 4 important, 3 neutral, 2 less important, 1 not important). The average value of each criterion was calculated, and the criteria used were those having an average value above 3. The next step was to calculate the weight of criteria using AHP. The purpose of this step was to rank the selected criteria.

Raut, Bhasin and Kamble (2011) combined DEMATEL and AHP. DEMATEL is used to determine the effect of one criterion on another. Meanwhile, AHP was used to give a weight to each criterion. Thus, it will know the importance of a criteria if used for the long term (viewed from DEMATEL) and for the short term (judging by the weight of AHP). If the company is concerned with short-term planning, then it can use AHP weight. However, the company focus for long-term planning, then it can use DEMATEL results. Mehregan, Hashemi and Merikhi (2014) ddevelop new approach (combination of DEMATEL and ISM) for evaluating and analysing criteria as well as extracting their internal relationships. This research can provide interrelationships among the criteria, thus aiding decision making to weight the criteria more efficiently.

4. Some Observations Remarks

4.1. Future Research is Based on Advantages and Weakness of the Methods

Delphi has some disadvantages. Delphi results are highly dependent on the expertise of the panelists. Therefore, the accuracy of the results depends on the selection of appropriate experts in the field. In addition, it is not easy to unify the perceptions of many experts. Although Kar and Pani (2014) attempt to fix this deficiency using a geometric mean, it can only be done for quantitative data only. For the Delphi method, panelists are experts in their field. However, they are human beings who have many limitations, leading the results to be ambiguous and inconsistent. As a result, Delphi is often done in several rounds. A proposal to overcome this weakness was made by Mahamadu, Mahdjoubi and Booth (2017). They proposed statistical tests to maintain stability between rounds, to end the process when there is no significant change in the panelist opinion between the rounds. One of the major drawbacks of Delphi is that it is expensive and takes a long time. It is not easy to gather many experts in one place and at one time. They are not necessarily willing to do so, even if paid. Many methods can overcome this deficiency by not using Delphi, but still using a few experts, such as ISM, DEMATEL, AHP, SEM, etc.

Another weakness of Delphi is a qualitative one, in determining the weight and priority of each criteria. To overcome this weakness, Luzon and El-Sayegh (2016), Kar (2015), and Banaeian (2015) proposed adding stages using AHP in the weighting of the criteria. However, the disadvantage is that if the consistency ratio is not consistent, then the Delphi process must be repeated until the pairwise comparison matrix becomes consistent. Therefore, it is necessary to improve Delphi so that it can yield a consistent pairwise comparison matrix.

DEMATEL is applied to find out the diagram of interrelation between criteria and subcriteria in supplier selection (Orji & Wei, 2014). The data input obtained from the questionnaire. This questionnaire should be filled in by an expert in supplier selection, who determines the intensity of the relationship between the criteria in supplier selection. Therefore, the magnitude of the influence between the criteria is identified in this method. The result obtained from DEMATEL is an impact-relation map (IRM) (Orji & Wei, 2014). This result is very relevant if used as a basis to develop the structural self-interaction matrix in the first step of ISM. So, the results of DEMATEL is suitable for input of ISM. This combination method in the supplier selection is introduced by Mehregan et al. (2014). However, the ISM's end result is to identify the driving force of each criteria only. Thus, it can be concluded that both methods (ISM and DEMATEL) are very suitable methods in the selection of criteria but can not rank the selected criteria. Merging both methods is inefficient, because they have almost the same goal. The other weakness of both methods (ISM and DEMATEL) is the result does not include the weight of criteria and takes a long time to calculate. Raut et al. (2011) proposed a new combination method of DEMATEL and AHP, but output of DEMATEL was not processed using AHP to obtain the weight of criteria.

A better model than ISM and DEMATEL is SEM. SEM is able to estimate the relationship between criteria that are multiply related (Sukwadi & Yang, 2014). This relationship is formed in a structural model (the relationship between dependent and independent constructs). SEM is able to illustrate the pattern of relationships between latent constructs and manifest criteria or indicator criteria (Sukwadi & Yang, 2014). SEM can perform three activities simultaneously, namely the validity and reliability of the instrument (equivalent to confirmatory factor analysis), testing the relationship model between latent criteria (equivalent to path analysis), and obtaining a useful model for prediction (equivalent to structural model or regression analysis) (Sukwadi & Yang, 2014). So, SEM is actually a hybrid technique that includes confirmatory aspects of factor analysis, path analysis, and regression. Although SEM has many advantages, there is little research on supplier selection using SEM.

The weakness of SEM is to focus more on affirming the relationships between criteria rather than focus on explaining their relationships. In this method, confirmatory analysis is used more than exploratory analysis. Another weakness is dependent on theoretical justification in the constructing of structural models and measurement models in the form of path diagrams. Justification of this theory is obtained from previous research. However, sometimes a field of research has not been studied before. Therefore, it is necessary to establish the justification of the theory from other models. ISM or DEMATEL is appropriate to build the justification of the theory in a particular field of research. So, the combination model of DEMATEL-SEM and ISM-SEM are suitable in determining the criteria for choosing a supplier.

4.2. Framework of Criteria Selection in the Supplier Selection

Based on the reviews of the methods in the previous section, we propose a direction guide for selection of criteria. The direction guide can be summarized as shown in Figure 10. In the first stage, we suggest modifying the Delphi model. The purpose of this modification is to save costs. The modification is to summarize the Delphi step so that it becomes one round only. It uses a new method in one round, so it can produce the same solution as using two rounds. ANOVA is required in testing the solution resulting from that one round. Another suggestion is that the questionnaire given once to each expert. Therefore, the expert is not collected in one place and one time, but visited by the surveyor.

In the second stage, a model can be developed of the related criteria using DEMATEL or ISM. This model is used to display how multiple criteria are related. Then, SEM is used to test the validity of those related by evaluating the linear relationships between a set of observed and unobserved criteria (Panuwatwanich, Stewart & Mohamed, 2008). ANOVA or multiple regressions cannot be performed on unobserved criteria (Lei & Wu, 2007). Therefore, the third stage uses SEM method to evaluate the correlation of between criteria in the supplier selection.

Some criteria should be taken into consideration in the supplier selection, but sometimes there are overlaps of information between criteria. The PCA method can reduce the number of these criteria without a loss of information. It can be displayed by new linear combinations that reflect the original information. Meanwhile, it still keeps most of the information of the original criteria. Therefore, the third stage uses PCA method to evaluate the criteria in the supplier selection comprehensively. In the last stage, there are several methods of multi criteria decision making (MCDM) that can be used, discussed below. These methods are capable to calculate the weighting of criteria and have been successfully applied in solving the problem of supplier selection.

Analytical Network Process (ANP) is a special form of AHP that includes the dependence of criteria and can be used to solve more complicated decision problems than AHP (Pang & Bai, 2013). In ANP, a network of criteria and subcriteria is created that controls the interaction between them (Bayazit, 2006). The general stages of the ANP are: (1) determine the network for each control criteria and combine the relevant criteria, (2) for each control criteria, create clusters versus a cluster matrix with zero or one as entries depending on whether the cluster on the left side affects or does not affect the clusters represented at the top of this matrix, (3) repeat the similar process for criteria versus criteria matrix, (4) derive eigenvectors and to form a supermatrix, (5) construct the supermatrix and rank the order of criteria (Bayazit, 2006).

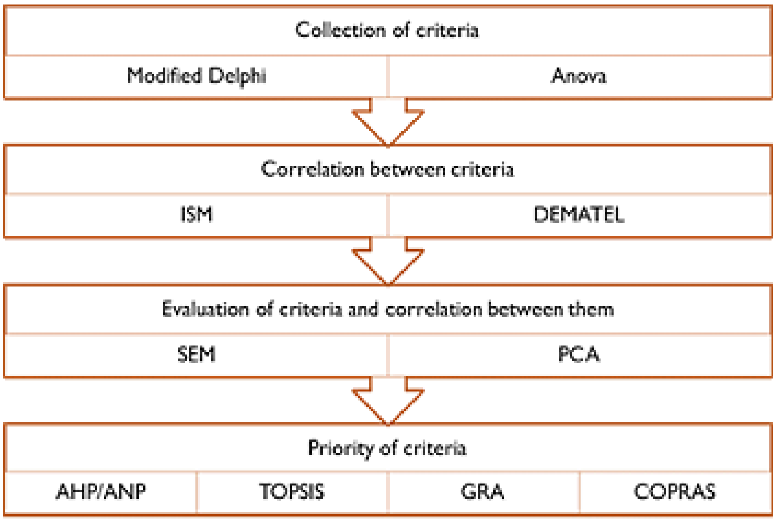

Figure 10. Direction guide of criteria selection

The Technique for Order Performance by Similarity to Ideal Solution (TOPSIS) takes into account the distance of each criteria assessment of the positive ideal and negative ideal, with a relative closeness index (RC) used for ranking based on maximizing of the distance from the negative ideal (Wood, 2016). The general stages of the TOPSIS are (1) construct a preference matrix, (2) determine the ideal and anti-ideal criteria, (3) calculate the distances of each criterion to ideal reference point and anti ideal reference point, (4) obtain the closeness coefficient and rank the criteria (Igoulalene, Benyoucef & Tiwari, 2015).

The fundamental idea of Grey Relational Analysis (GRA) is that relationship closeness is judged based on the level of similarity using limited amounts of data (Bali, Kose & Gumus, 2013). GRA is capable in the problem solving with complicated of the interrelationships between multiple criteria with ith discrete data and incomplete information (Li, Yamaguchi & Nagai, 2007). The general stages of the GRA are (1) the assessment of criteria of the decision maker, (2) the making of grey decision matrix, (3) normalize grey decision matrix, (4) making the ideal criteria as a referential criterion, (5) calculate the gray possibility degree between compare criteria, (6) rank the order of criteria (Li et al., 2007).

COmplex PRoportional ASsessment of alternatives (COPRAS) is a decision evaluation method based on variability of the data of each criterion. The steps of COPRAS are (1) select data (smallest and biggest value) from each criterion, (2) contruct the matrix of decision making using data (column) and criteria (row), (3) normalize the decision matrix; (4) calculate P_j (larger value are more preferable) using Equation (4) where *i* is index of data, *j* is index of criteria, $\bar{\hat{x}}_{ji}$ is maximum value of the data *i* of criteria *j*, and $\underline{\hat{x}}_{ji}$ is minimum value of the data *i* of criteria *j*, (5) Calculate the utility degree of each criterion (Q_j)(Equation (5)) and rank the criteria based on the utility degree (Zavadskas, Turskis, Tamošaitiene & Marina, 2008).

$$P_j = \frac{1}{2}\sum_{i=1}^{k}(\underline{\hat{x}}_{ji} + \bar{\hat{x}}_{ji}) \tag{4}$$

$$Q_j = \frac{Q_j}{Q_{\max}} x100\% \tag{5}$$

5. Conclusion

This paper provides a systematic literature review of articles published in 2008–2018 on selection techniques in supplier criteria. A total of 34 journal articles were carefully selected and reviewed in detail. We systematically summarized four techniques of selection criteria that have been applied, the Delphi method, statistical method, MCDM, and mixed method. Given the shortcomings of this method, the possibility of further development and improvement is still open. The paper provides valuable accumulated knowledge on current research and recommendations for future studies. Some methods in MCDM are still rarely used in the selection of supplier criteria. However, discussion of the experts should still be used in future research.

This study has two main limitations. Our review focuses on the application of techniques of selection criteria in the supplier selection. Review articles published 2008–2018 and searched based on the keyword "selection of supplier criteria" and "selection of vendor criteria." A number of articles published in late 2018, if any, may not be included in the survey.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

References

Abdel-Basset, M., Manogaran, G., Gamal, A., & Smarandache F. (2018). A hybrid approach of neutrosophic sets and DEMATEL method for developing supplier selection criteria. *Design Automation for Embedded System*. *In Press*. https://doi.org/10.1007/s10617-018-9203-6

Bali, O., Kose, E., & Gumus, S. (2013). Green supplier selection based on IFS and GRA. *Grey Systems: Theory and Application*, 3(2), 158-176. https://doi.org/10.1108/GS-04-2013-0007

Banaeian, N., Nielsen, I.W., Mobli, H., & Omid, M. (2014). Green supplier selection edible oil production by a hybrid model using delphi method and green data envelopment analysis (GDEA). *Management and Production Engineering Review*, 5(4), 3-8. https://doi.org/10.2478/mper-2014-0030

Banaeian, N., Nielsen, I.W., Mobli, H., & Omid, M. (2015). Criteria definition and approaches in green supplier selection – a case study for raw material and packaging of food industry. *Production and Manufacturing Research*, 3(1), 149-168. https://doi.org/10.1080/21693277.2015.1016632

Bayazit, O. (2006). Use of analytic network process in vendor selection decisions. *Benchmarking*, 13(5), 566-579. https://doi.org/10.1108/14635770610690410

Chai, J., Liu, J. N.K., & Ngai, E.W.T. (2013). Application of decision-making techniques in supplier selection: A systematic review of literature. *Expert Systems with Applications*, 40(10), 3872-3885. https://doi.org/10.1016/j.eswa.2012.12.040

Chang, B., Chang, C.W., & Wu, C.H. (2011). Fuzzy DEMATEL method for developing supplier selection criteria. *Expert Systems with Applications*, 38(3), 1850-1858. https://doi.org/10.1016/j.eswa.2010.07.114

Chen, A., Hsieh, C.Y., & Wee, H.M. (2014). A resilient global supplier selection strategy—a case study of an automotive company. *The International Journal Advance Manufacturing Technology*, 87(5), 1475-1490. https://doi.org/10.3846/16111699.2013.807870

Chen, K.L., Yeh, C.C., & Huang, J.C. (2014). Supplier selection using a hybrid model for 3C industry. *Journal of Business Economics and Management,* 15(4), 631-645. https://doi.org/10.3846/16111699.2013.807870

El Mokadem, M. (2017). The classification of supplier selection criteria with respect to Lean or Agile manufacturing strategies. *Journal of Manufacturing Technology Management*, 28(2). https://doi.org/10.1108/JMTM-04-2016-0050

Eshtehardian, E., Ghodousi, P., & Bejanpour, A. (2013). Using ANP and AHP for the Supplier Selection in the Construction and Civil Engineering Companies; Case Study of Iranian Company. *Journal of Civil Engineering*, 17(2), 262-270. https://doi.org/10.1007/s12205-013-1141-z

Felice, F.D., Deldoost, M.H., & Faizollahi, M. (2015). Performance Measurement Model for the Supplier Selection Based on AHP. *International Journal of Engineering Business Management*, 7(17), 1-13. https://doi.org/10.5772/61702

Feng, Q., Li, M., & Gong, D. (2014). Research on the Competitiveness of Crediting Rating Industry using PCA Method. *Journal of Industrial Engineering and Management*, 7(5), 1268-1282. https://doi.org/10.3926/jiem.1275

Genovese, A., Koh, S.C.L., Bruno, G., & Esposito, E. (2013). Greener supplier selection: state of the art and some empirical evidence. *International Journal of Production Research*, 51(10), 2868-2886. https://doi.org/10.1080/00207543.2012.748224

Girubha, J., Vinodh, S., & Vimal, K.E.K. (2016). Application of Interpretative Structural Modelling integrated Multi Criteria Decision Making methods for sustainable supplier selection. *Journal of Modelling in Management*, 11(2), 358-388. https://doi.org/10.1108/JM2-02-2014-0012

Govindan, K., Rajendran, S., Sarkis, J., & Murugesan, P. (2015). Multi criteria decision making approaches for green supplier evaluation and selection: a literature review. *Journal of Cleaner Production*, 98, 66-83. https://doi.org/10.1016/j.jclepro.2013.06.046

Guo, C., Guan, Z., & Song, Y. (2012). Research on bulk-cargo-port berth assignment based on priority of resource allocation. *Journal of Industrial Engineering and Management*, 6(1), 276-288. https://doi.org/10.3926/jiem.673

Gupta, R.O., & Walton, A. (2016). Interpretive structural modelling to assess third party logistics providers, *World Review of Intermodal Transportation Research*, 6(1), 59-73. https://doi.org/10.1504/WRITR.2016.078155

Handayani, N.U., Cakravastia, A., Diawati, L., & Bahagia, S.N. (2012). A conceptual assessment model to identify phase of industrial cluster life cycle in Indonesia. *Journal of Industrial Engineering and Management*, 5(1), 198-228. https://doi.org/10.3926/jiem.447

Ho, W., Xu, X., & Dey, P.K. (2010). Multi-criteria decision making approaches for supplier evaluation and selection: A literature review. *European Journal of Operational Research*, 202(1), 16-24. https://doi.org/10.1016/j.ejor.2009.05.009

Igarashi, M., de Boer, L., & Fet, A.M. (2013). What is required for greener supplier selection? A literature review and conceptual model development. *Journal of Purchasing & Supply Management*, 19(4), 247-263. https://doi.org/10.1016/j.pursup.2013.06.001

Igoulalene, I., Benyoucef, L., & Tiwari, M.K. (2015). Novel fuzzy hybrid multi-criteria group decision making approaches for the strategic supplier selection problem. *Expert Systems with Applications*, 42(7), 3342-3356. https://doi.org/10.1016/j.eswa.2014.12.014

Imeri, S., Shahzad, K., Takala, J., Liu, Y., Sillanpaa, I., & Ali, T. (2015). Evaluation and selection process of suppliers through analytical framework: An empirical evidence of evaluation tool. *Management and Production Engineering Review*, 6(3), 10-20. https://doi.org/10.1515/mper-2015-0022

Kar, A.K. (2015). A hybrid group decision support system for supplier selection using analytic hierarchy process, fuzzy set theory and neural network. *Journal of Computational Science*, 6, 23-33. https://doi.org/10.1016/j.jocs.2014.11.002

Kar, A.K., & Pani, A.K. (2014). Exploring the importance of different supplier selection criteria. *Management Research Review*, 37(1), 89-105. https://doi.org/10.1108/MRR-10-2012-0230

Kim, M., & Boo, S. (2010). Understanding Supplier-Selection Criteria: Meeting Planners' Approaches to Selecting and Maintaining Suppliers. *Journal of Travel & Tourism Marketing*, 27(5), 507-518. https://doi.org/10.1080/10548408.2010.499062

Kumar, S., Gorane, S., & Kant, R. (2015). Modelling the supplier selection process enablers using ISM and fuzzy MICMAC approach. *Journal of Business & Industrial Marketing*, 30(5), 536-551. https://doi.org/10.1108/JBIM-01-2013-0012

Lam, K.C., Tao, R., & Lam, M.C.K. (2010). A material supplier selection model for property developers using Fuzzy Principal Component Analysis. *Automation in Construction*, 19(5), 608-618. https://doi.org/10.1016/j.autcon.2010.02.007

Lei, P.W., & Wu, Q. (2007). Introduction to structural equation modeling: Issues and practical considerations. *Educational Measurement: Issues and Practice*, 26(3), 33-43. https://doi.org/10.1111/j.1745-3992.2007.00099.x

Li, G.D., Yamaguchi, D., & Nagai, M. (2007). A grey-based decision-making approach to supplier selection. *Mathematical and Computer Modelling*, 46(3-4), 573-581. https://doi.org/10.1016/j.mcm.2006.11.021

Lin, P.C., & Lin, K.Y. (2008). Supplier Selection Criteria for Dried Striped Mullet Roe Processors. *North American Journal of Fisheries Management*, 28(1), 165-175. https://doi.org/10.1577/M06-203.1

Luzon, B., & El-Sayegh, S.M. (2016). Evaluating supplier selection criteria for oil and gas projects in the UAE using AHP and Delphi. *International Journal of Construction Management*, 16(2), 175-183. https://doi.org/10.1080/15623599.2016.1146112

Masi, D., Micheli, G.J.L., & Cagno, E. (2013). A meta-model for choosing a supplier selection technique within an EPC company. *Journal of Purchasing & Supply Management*, 19(1), 5-15. https://doi.org/10.1016/j.pursup.2012.07.002

Mahamadu, A.M., Mahdjoubi, L., & Booth, C.A. (2017). Critical BIM qualification criteria for construction pre-qualification and selection. *Architectural Engineering and Design Management,* 13(5), 326-343. https://doi.org/10.1080/17452007.2017.1296812

Mathiyazhagan, K., Sudhakar, S., & Bhalotia, A. (2018). Modeling the criteria for selection of suppliers towards green aspect: a case in Indian automobile industry. *Opsearch*, 55(1), 65-84. https://doi.org/10.1007/s12597-017-0315-8

Mavi, K.M., & Shahabi, H. (2015). Using fuzzy DEMATEL for evaluating supplier selection criteria in manufacturing industries. *International Journal of Logistics Systems and Management,* 22(1) 15-42. https://doi.org/10.1504/IJLSM.2015.070889

Mehregan, M.R., Hashemi, S.H., & Merikhi, A.K.B. (2014). Analysis of interactions among sustainability supplier selection criteria using ISM and fuzzy DEMATEL. *International Journal of Applied Decision Sciences*, 7(3), 270-294. https://doi.org/10.1504/IJADS.2014.063226

Mohanty, M.K., & Gahan, P. (2011). Supplier evaluation & selection attributes in discrete manufacturing industry — empirical study on Indian manufacturing industry. *International Journal of Management Science and Engineering Management*, 6(6), 431-441. https://doi.org/10.1080/17509653.2011.10671193

Olorunniwo, F., & Jolayemi, J. (2014). Using supplier selection sub-criteria: selected illustrative demographic analyses. *International Journal of Business Performance and Supply Chain Modelling*, 6(1), 94-108. https://doi.org/10.1504/IJBPSCM.2014.058897

Orji, I.J., & Wei, S. (2014). A Decision Support Tool for Sustainable Supplier Selection in Manufacturing Firms. *Journal of Industrial Engineering and Management*, 7(5), 1293-1315. https://doi.org/10.3926/jiem.1203

Pang, B., & Bai, S. (2013). An integrated fuzzy synthetic evaluation approach for supplier selection based on analytic network process. *Journal of Intelligent Manufacturing*, 24(1), 163-174. https://doi.org/10.1007/s10845-011-0551-3

Panuwatwanich, K., & Nguyen, T.T. (2017). Influence of organisational culture on total quality management implementation and firm performance: evidence promthe vietnamese construction industry. *Management and Production Engineering Review,* 8(1), 5-15. https://doi.org/10.1515/mper-2017-0001

Panuwatwanich, K., Stewart, R.A., & Mohamed, S. (2008). The role of climate for innovation in enhancing business performance: the case of design firms. *Engineering, Construction and Architectural Management*, 15(5), 407-422. https://doi.org/10.1108/09699980810902712

Parthiban, P., Zubar, H.A., & Garge, C.P. (2012). A multi criteria decision making approach for suppliers selection. *Procedia Engineering*, 38, 2312-2328. https://doi.org/10.1016/j.proeng.2012.06.277

Patra, S.K., Dash, P.K. (2015). Designing a computational tool for supplier selection using analytical hierarchy process. *International Journal of Mathematics in Operational Research*, 7(4), 361-371. https://doi.org/10.1504/IJMOR.2015.070187

Punniyamoorthy, M., Mathiyalagan, P., & Parthiban, P. (2011). A strategic model using structural equation modeling and fuzzy logic in supplier selection. *Expert Systems with Applications*, 38(1), 458-474. https://doi.org/10.1016/j.eswa.2010.06.086

Punniyamoorty, M., Mathiyalagan, P., & Lakshmi, G. (2012). A combined application of structural equation modeling (SEM) and analytic hierarchy process (AHP) in supplier selection. *Benchmarking*, 19(1), 70-92. https://doi.org/10.1108/14635771211218362

Raut, R.D., Bhasin, H.V., & Kamble, S.S. (2011). Evaluation of supplier selection criteria by combination of AHP and fuzzy DEMATEL method. *International Journal of Business Innovation and Research*, 5(4), 359-392. https://doi.org/10.1504/IJBIR.2011.041056

Saaty, T.L. (1990). How to make a decision: The Analytic Hierarchy Process. *European Journal of Operational Research*, 48(1), 9-26. https://doi.org/10.1016/0377-2217(90)90057-I

Sukwadi, R., & Yang, C.C. (2014). Determining Service Improvement Priority in a Zoological Park. *Journal of Industrial Engineering and Management*, 7(1), 1-10. https://doi.org/10.3926/jiem.644

Tsai, S.B., Saito, R., Lin, Y.C., & Chen, Q. (2015). Discussing measurement criteria and competitive strategies of green suppliers from a green law perspective. *Journal of Engineering and Manufacture*, 229(51), 135-145. https://doi.org/10.1177/0954405414558740

Tsai, S.B., Wei, Y.M., Chen, K.Y., Xu, L., Du, P., & Lee, H.C. (2016). Evaluating green suppliers from a green environmental perspective. *Environment and Planning B: Planning and Design*, 43(5), 941-959. https://doi.org/10.1177/0265813515600897

Tsaur, S.H., & Ling, W.R. (2014). Selection criteria of an overseas travel intermediary for group package tours: application of fuzzy analytic hierarchy process. *Journal of Hospitality & Tourism Research*, 38(3), 283-303. https://doi.org/10.1177/1096348012451457

Voss, D. (2013). Supplier choice criteria and the security aware food purchasing manager. *The International Journal of Logistics Management*, 24(3), 380-406. https://doi.org/10.1108/IJLM-03-2013-0029

Wood, D.A. (2016). Supplier selection for development of petroleum industry facilities, applying multi-criteria decision making techniques including fuzzy and intuitionistic fuzzy TOPSIS with flexible entropy weighting. *Journal of Natural Gas Science and Engineering*, 28, 594-612. https://doi.org/10.1016/j.jngse.2015.12.021

Xu, L., Kumar, D.T., Shankar, K.M., Kannan, D., & Chen, G. (2013). Analyzing criteria and sub-criteria for the corporate social responsibility-based supplier selection process using AHP. *The International Journal of Advanced Manufacturing Technology*, 68(1), 907-916. https://doi.org/10.1007/s00170-013-4952-7

Xu, W., Zhang, Q., & Ma, J. (2013). The relationship among customer demand, competitive strategy and manufacturing system functional objectives. *Journal of Industrial Engineering and Management*, 6(4), 1238-1254. https://doi.org/10.3926/jiem.802

Xu, J., Liang, L., & Li, Y. (2013). Service requirement for terminal delivery: An empirical study from the perspective of online shoppers. *Journal of Industrial Engineering and Management*, 6(4), 1223-1237. https://doi.org/10.3926/jiem.879

Zavadskas, E.K., Turskis, Z., Tamošaitiene, J., & Marina, V. (2008). Multicriteria selection of project managers by applying grey criteria. *Ukio Technologinis ir Ekonominis Vystymas*, 14(4), 462-47. https://doi.org/10.3846/1392-8619.2008.14.462-47

Journal of Industrial Engineering and Management, 2018 (www.jiem.org)