International Journal of Advances in Applied Sciences (IJAAS)
Vol. 12, No. 4, December 2023, pp. 384~395
ISSN: 2252-8814, DOI: 10.11591/ijaas.v12.i4.pp384-395

MCDM-AHP and PROMETHEE methods integrated for base service strategy vendor evaluation and selection

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Article Info

Article history:

Received Jul 20, 2023
Revised Oct 10, 2023
Accepted Oct 18, 2023

Keywords:

Expert choice apps
Mathematical algebra matrices
MCDM-AHP concept
PROMETHEE elimination model
Vendor evaluation and selection

ABSTRACT

Business competition is very important in controlling product-savvy customers. Strong basic service techniques will be the main factor that binds vendors as the final destination in the supply chain through the strength of business network processes. This research aims to create a strategic basis for evaluating and selecting vendors through the integration process services of the multi-criteria decision-making method analytic hierarchy process (MCDM-AHP) and preference ranking organization method for enrichment evaluation (PROMETHEE) methods. Empirical studies show how this approach can provide optimal decision support for the vendor evaluation and selection process. Eight different types of criteria are required in its apps and must be realized as a barometer of the strategic basis for selecting vendors so that business processes are of high quality. These criteria include quality of goods, payment methods, payment terms, minimum transactions, discounts, delivery times, inventory, and service. The optimal weight for each criterion will be determined based on its importance to the synthesis process and its feasibility tested using mathematical algebra matrices and expert choice apps. Decision-making was based on the results of ranking evaluation of selected vendors through the development of 342 preference matrices, ten vendors were deemed worthy of acceptance and nine other vendors were rejected.

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1. INTRODUCTION

The robustness of the supply chain is a significant consideration in the development of business operations. The stabilization of a vendor's supply chain becomes a highly intricate challenge when confronted with multiple criteria and conflicting types of criteria. To ensure the continuity of business process turnover, it is imperative to employ an appropriate analytical approach for the development of a supply chain rotation wheel that is both highly efficient and reliable. The utilization of the analytic hierarchy process (AHP) method is one potential approach for evaluating and selecting solutions [1]. The objective of this study is to assess and choose vendors during the supply chain provision phase to ensure the effective and efficient maintenance of the supply chain, as well as the distribution of goods to downstream entities at competitive and affordable prices.

The assessment and selection procedure that will be conducted for multiple vendors employs an integrated method. The utilization of an integrated method approach can serve as a decision support mechanism [2] in the assessment and choice of vendors in a comprehensive manner. The vendor's role holds a position of prominence in the downstream sector. It surpasses the significance of the sales transaction process [3]. The ability to effectively navigate multiple downstream boundaries is directly correlated with the abundance of business prospects within supply chain pathways [4]. Therefore, it is imperative to adopt a suitable method for assessing and choosing vendors, to establish a supply chain procurement system that exhibits enhanced potential [5], [6].

The utilization of an integrated method approach is deemed advantageous in managing the regulations associated with the vendor evaluation and selection process [7]. This study aims to present a comprehensive analysis of vendor evaluation and selection [8], [9], to establish an efficient and effective procurement and supply system for goods. This study will examine the utilization of the multi-criteria decision-making method analytic hierarchy process (MCDM-AHP) [10], [11] in achieving optimal integrity, in conjunction with the preference ranking organization method for enrichment evaluation (PROMETHEE) [12]–[14]. The efficacy of these two method can be observed through their respective functions. The MCDM-AHP approach serves as a comparative assessment by assigning importance values to multiple criteria, with the eigenvector value serving as the basis for evaluation. This has been substantiated by previous studies utilizing mathematical algebra matrices [15], [16] as well as expert choice apps [16], [17]. The significance of the eigenvector's magnitude is a remarkable phenomenon in rating systems and has garnered extensive utilization [18], The process involves iteratively multiplying matrices until the reduction in the value of the last eigenvector is indistinguishable from that of the previous eigenvector [19]. Ultimately, the optimal eigenvector value will be determined, signifying the completion of the eigenvector calculation process without any further iterations [20]. The ultimate determination of the eigenvector value will be employed as a measure of reliability in the computational procedure alongside other methods [21] such as the PROMETHEE method. The PROMETHEE method exhibits similarities to the MCDM-AHP method in its approach to establishing a ranking system [22]. One notable distinction between these two methods lies in their utilization of a ranking technique that exhibits both consistency and contradiction. This study employs criteria that exhibit both concordance and contradiction, wherein certain criteria are interpreted to prioritize higher values as superior, while others prioritize lower values as superior. The PROMETHEE method serves a distinct purpose in the identification and evaluation of criteria. The normalization process employed for criteria of this nature involves categorizing the criteria as either contributing to the final value through addition or detracting from it through subtraction. The user has provided a numerical reference without any accompanying text or context. The outcome of this process will serve as a tool for making informed decisions regarding the evaluation and selection of vendors.

From the elaboration that has been submitted, several contributions can be explained to this research i) Providing an overview of new findings on the integrity of the two MCDM-AHP methods as evidenced by the mathematical algebra matrices as a stage of the iteration process to find optimal eigenvector values and proven through expert choice apps through identical input gives the same picture as the mathematical algebra matrices method and the of expert choice apps to the acquisition of eigenvector values. It is proven through this research that two different approaches to the MCDM-AHP method can provide identical and accurate results and ii) The PROMETHEE method applied in this research is not as usual but provides more difficult obstacles in data processing because the type of criteria used in this research is contradictory, where the types of criteria used contradict each other in meaning, this is proven by the data processing which contains the meaning of the largest value is the best value and the smallest value is the best. Data processing like this is rarely carried out by researchers, if data processing like this is not understood properly and correctly it will result in errors in the manifestation of decision support becoming distorted.

2. RESEARCH METHOD

This section will explain the steps to be achieved through an algorithm for the integrated process of the two main methods as a reference for solutions that handle the supply chain with the MCDM-AHP which strengthens the concept of multi-criteria decision-making with the PROMETHEE method. The MCDM-AHP method will strengthen the process of obtaining the eigenvector value with iteration stages until it finds no difference between the last eigenvector value and the previous eigenvector value, meaning that the acquisition of the eigenvector value reaches the optimal point. The second approach is by testing through expert choice apps to measure the truth of the eigenvector values reaching the eligibility point as seen from the calculation of the algebra matrices through the consistency and inconsistency amounts through expert choice apps. The second one is the PROMETHEE method, through the acquisition of optimal eigenvector, which is a combination of mathematical calculations for the elimination process as a preference index builder and arranged into matrices as a ranking measure. See Figure 1 for a more detailed understanding.

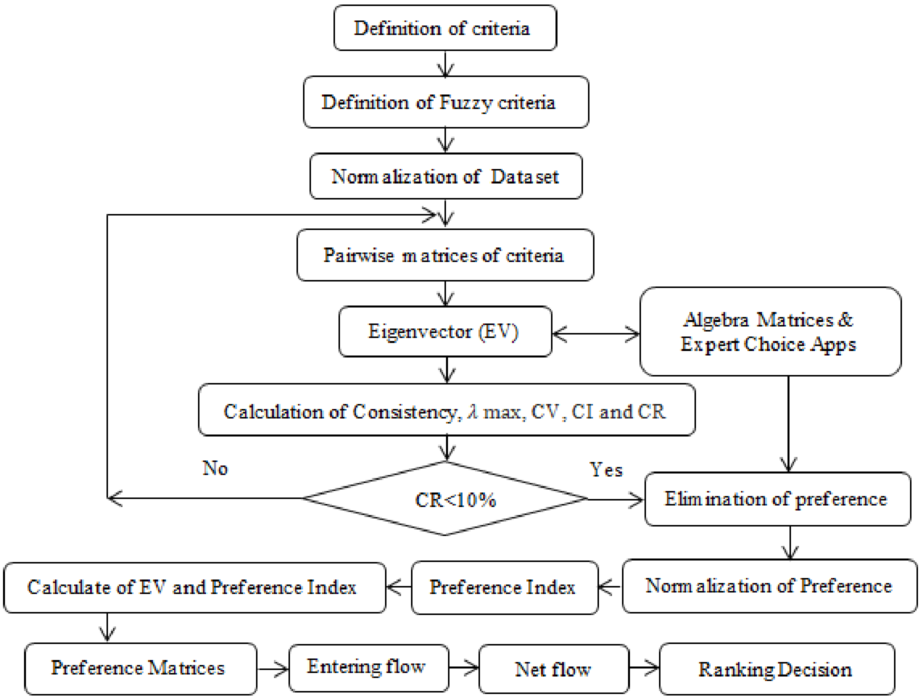

Figure 1. MCDM-AHP-PROMETHEE algorithm

2.1. Multi-criteria decision-making method analytic hierarchy process

MCDM-AHP is a method that has many assessment criteria [23], [24]. The assessment parameters are seen from a number of criteria that will be used, these criteria as an assessment measuring tool that have different characteristics from the assessment criteria [25], [26]. In general, the criteria used have the same characteristics, that is, the assessment with the highest value is the best, but this is not the case, there are a number of criteria that have the smallest meaning as the best, and some even use both characteristics. The use of these two properties in research is very difficult to evaluate, so a normalization process is needed that is not normally used. The calculation concept contained in the MCDM-AHP method generally uses the concept of valuation based on the value of interest [27]–[29], therefore MCDM-AHP in this study is only used for weighting that is owned by a number of criteria and not up to the rating assessment of the alternatives. This is done because MCDM-AHP only has an assessment concept that has the first meaning, that is, the greatest value is the best value (HB), while for the assessment of the vendor evaluation process [30] not all of them have properties that apply to understanding the criteria that the biggest is the best, but some characteristics of the criteria mean the smallest is the best (LB), so another method is needed that can and is able to apply concepts with contradictory alternative properties, so they must be integrated with other methods that are able to deal with problems like this. The equation that can be applied to the MCDM-AHP method [31], [32] can be seen in the following equation.

The first boundary is the work carried out in connection with MCDM-AHP starting with defining criteria sourced from experts who have long worked in the field of supply chains. Compile a comparison of criteria based on their importance values which will be used as pairwise matrices with the matrix elements shown in (1) using a comparison scale and the number of criteria being compared can be used (2). In this way, a questionnaire can be prepared to serve as an entry for respondents. Assessing vendors requires the role of an entity responsible for compiling fuzzy criteria using an interval scale to determine dataset matrices that are ready to be processed into normalization datasets. The purpose of preparing pairwise matrices criteria is to determine the amount of consistency, namely consistency vector (3), consistency index (4), and consistency ratio (5). The consistency ratio can be processed with the help of a random index (RI) which is adjusted to the size of the order matrices used. Processing pairwise matrices criteria produces eigenvectors as a characteristic of MCDM-AHP and will be tested using two approaches, namely mathematical algebra matrices and expert choice apps to find the optimum eigenvector which is carried out through iteration stages until there is no difference between the last iteration's eigenvector and the previous eigenvector. Finding the optimum eigenvector is the key to collaborating with other methods as an assessment of the weight of alternatives for all criteria whose criteria weights have been found through the optimum eigenvector.

$$DM_{(i,j)} = \begin{matrix} AM_1 \\ AM_2 \\ AM_3 \\ \vdots \\ AM_i \end{matrix} \begin{bmatrix} em_{(1,1)} & em_{(1,2)} & em_{(1,3)} & \cdots & em_{(1,j)} \\ em_{(2,1)} & em_{(2,2)} & em_{(2,3)} & \cdots & em_{(2,j)} \\ em_{(3.1)} & em_{(3,2)} & em_{(2,4)} & \cdots & em_{(3,j)} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ em_{(i,1)} & em_{(i,2)} & em_{(i,3)} & \cdots & em_{(i,j)} \end{bmatrix} \quad (1)$$

Where DM is decision matrices, AM is alternative matrices, em is element matrices, i is row, and j is column.

$$CN = \frac{n*(n-1)}{2} \quad (2)$$

Where CN is the comparison number and n are the matrices ordo.

$$CV = \frac{EV}{DM} \quad (3)$$

Where CV is the consistency vector, EV is the eigenvector, and DM is the decision matrix.

$$CI = \frac{(\lambda \text{ max} - \text{n})}{(n-1)} \quad (4)$$

Where CI is consistency index, λ max is the length of matrices, and n are matrices ordo.

$$CR = \frac{CI}{RI} \quad (5)$$

Where CR is the consistency ratio, CI is the consistency index, and RI is a random index. To get the consistency index, an RI auxiliary table is needed as a measure of the number of orders used, and pay attention to Table 1, each order has a different value [33]. Obtaining a CR value, will have a major influence on decision-making support, the final result of which is accepted or rejected.

Table 1. RI [34], [35]

Ordo matrices	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0	0	0.6	0.9	1.12	1.24	1.32	1.41	1.45	1.48	1.51	1.48	1.56	1.57	1.58

2.2. Preference ranking organization method for enrichment evaluation

PROMETHEE is a method used to bridge research problems that are flexible, meaning research problems that have criterion characteristics with conditions that are contradictory or in line. The PROMETHE method is commonly used by researchers to provide rankings [36] to a number of alternatives that are the largest is the best, but this study tries to apply a different concept in general, namely to apply an evaluation process to vendors using many criteria researchers, where the criteria used are contradictory [37]. The assessment of these criteria will affect the results of the assessment of support for decision-making. The influence on the results of decision support can be seen from the nature of the criteria, the criteria that are of different value are the best values that will provide added value to decision-making support, while the second trait is that the smallest value is the best value, the nature of this criterion will provide a reduction in the process of decision support decision. To provide an assessment that is in line with conditions like this, a normalization stage is needed so that the assessment is in line. This conversion process will be carried out at the dataset processing stage which has a number of alternative assessments. The conversion process with PROMETHEE through the concept of eliminating a number of alternatives, where alternative values that are less than zero will be eliminated and conversely those that are more than zero will be processed continuously to be adjusted to the weighted value. Obtained from the MCDM-AHP method on the acquisition of eigenvector values. The equation that can be applied to the PROMETHE method is as follows.

The second boundary, through proof of the first boundary, provides opportunities for collaboration with the PROMETHEE method to complete the ranking. Refers to the algorithm that has become a research framework. The results obtained from the normalization dataset must be compared one by one as a whole for each of the 19 alternative vendors. The alternative comparisons carried out will be matrix elements with positions according to the criteria column being compared. Criteria of type HB are compared using (6), while criteria of type LB are compared using (7). Seeing the fact that all element matrices that are compared will give positive and negative values. A positive value will increase the value and vice versa does not affect the final alternative result. A positive value will be applied to each criterion column which will be multiplied by the optimum eigenvector value and as a whole for each alternative compared to each criterion column. The results are two-dimensional matrices. The sum of the results of multiplying each matrix as a whole in the column position is said to be the leaving flow which can be searched for using (8) and the sum of the results of multiplying the matrices as a whole in the row position is said to be the entering flow which enters using (9). Secondly, obtaining the number of columns and rows in two-dimensional matrices is still said to be a partial decision so it must be combined as support for the final decision which can be processed using (10).

$$R_{(i,j)} = \frac{(X_{(i,j)} - X'_j)}{X^*_j - X'_j)} \tag{6}$$

Where $R_{(i,j)}$ is index preference in position (i,j), $X_{(i,j)}$ is element data matrices in position (i,j), X^*_j is maximum of element matrices, and X'_j is the minimum of element matrices.

$$R_{(i,j)} = \frac{(X_{(i,j)} - X^*_j)}{X'_j - X^*_j)} \tag{7}$$

Where $R_{(i,j)}$ is index preference in position (i,j), $X_{(i,j)}$ is element data matrices in position (i,j), X^*_j is maximum of element matrices, and X'_j is the minimum of element matrices.

$$\Phi^+(i) = \frac{1}{(n-1)} \sum_{i=1}^{n} \pi(i,i) \tag{8}$$

Where $\Phi^+(i)$ is leaving flow and n is the number of alternatives.

$$\Phi^-(i) = \frac{1}{(n-1)} \sum_{i=1}^{n} \pi(i,i) \tag{9}$$

Where $\Phi^-(i)$ is entering flow and n is the number of alternatives.

$$\Phi(i) = \Phi^+ - \Phi^-(i) \tag{10}$$

Where $\Phi(i)$ is net flow.

2.3. Integrated process

The integration process of the two methods can be carried out after the process of weighing the criteria using the MCDM-AHP method and the elimination process using the PROMETHEE method for a number of alternatives, then the integration of the two methods can be carried out [38], [39] by providing a multiplication assessment of all alternatives according to the ownership of the eigenvector value of each indexed data criterion. The accumulative multiplication results obtained from each matrix position for the data elements are used as preference index data which will be compiled into two-dimensional matrices and will be a benchmark for evaluating all alternatives based on two assessments of leaving flow and entering flow. The ranking process can be obtained through the accumulation of both processes which is called net flow. Another integrated research is MCDM-AHP and PROMETHEE combined with four different methods [40] as decision support. The integration of MCDM-AHP and PROMETHEE provides some acceptable alternatives. This shows support for the evaluation and selection of a number of vendors as an alternative that has been selected optimally.

3. RESULTS AND DISCUSSION

The initial step in the assessment of vendors for the supply chain involves the establishment of criteria. These criteria have been determined based on the input of 120 respondents who have experience working with vendors in the supply chain industry. A total of eight key criteria have been identified for the evaluation of vendors. The MCDM-AHP method will be employed to prioritize the criteria based on their respective importance values. A total of eight criteria will be assessed and their importance values will be compared. The utilization of (1) facilitates the transformation of the comparative analysis of the eight criteria into a total of 28 criterion comparisons, as indicated by (2). The available comparisons yield decision matrices with a total of eight orders. These matrices are presented in Table 2 as decision matrices. The matrices presented in Table 2 can be demonstrated through two distinct methods. The first approach involves computing the algebraic matrices, which substantiates the magnitude of the eigenvector values generated via an iterative process spanning up to five iterations. The iterative process is employed to obtain the most favorable eigenvector values. This implies that there is no discernible distinction in the evaluation of 120 participants who contributed their input through the utilization of a questionnaire as an instrument, compared to the alternative method of employing the expert choice apps. The latter approach involves treating the optimal eigenvector value with expert choice, while also determining the level of inconsistency with a resulting value of 0.3. This finding indicates that the research outcomes pertaining to decision-making support are highly credible and deserving of acceptance. The specific information will be presented comprehensively in Table 3.

Figure 2 besides providing an overview of the acquisition of the eigenvector value can also determine the amount of inconsistency, with a value of 0.03; which means that decision-making support is acceptable so that the integration process with other methods can be continued. The integration process with the PROMETHEE method can be continued in the vendor evaluation and selection process. By paying attention to Figure 2, it is shows that all the eigenvector acquisition values of the eight criteria through the synthesis stage give identical values to the magnitude of the eigenvector acquisition values compared to the algebra matrices stages. This proves that the same results with different approaches show progress in proving the truth of the research results. Thus the acquisition of optimal eigenvector values can have a major influence on the integrated apps of the two MCDM-AHP methods with PROMETHEE. Research that uses a collaboration of a number of methods like this must have standards that can be said to be continued or not with other methods. In this research, the continuation of the process of the MCDM-AHP method is determined based on the resulting eigenvector value which must find the optimum point, this is a good standard to be able to collaborate with the PROMETHEE method. Prove the acquisition of the eigenvector quantities can be done using expert choice apps, where this proof is done by displaying the entry of the importance values of the criteria which can be seen in Table 3 as pairwise matrices and the results of calculations to produce eigenvector value.

Look at Table 3 which is an entry for forming pairwise matrices which are somewhat different from algebra matrices. Pairwise matrices with expert choice apps only show the upper matrices triangle and the nature of the entry is only a part of the whole matrices. The other element matrices are hidden in the coding process of the expert choice apps so that the reciprocal element matrices are not shown in the entry pairwise matrices. In essence, the implementation is the same in the process of using algebra matrices.

Evaluation and selection of vendors are determined based on eight criteria with different types of criteria that have contradictory understandings. The contradictory understanding of the criteria can be seen from their nature, namely, the understanding that the largest value is the best (HB) and the understanding of the smallest value is the best (LB). The eight criteria used as measurement barometers are quality of good (QG), payment method (PM), payment term (PT), discount (DS), inventory (IN), and service (SV), these six criteria have HB characteristics. The other two criteria are LB which includes minimum transaction (MT) and delivery time (DT).

Table 2. Pairwise matrices using algebra matrices

Criteria	QG	PM	PT	MT	DS	DT	IN	SV	Eigenvector
QG	1.000	1.453	1.943	2.923	3.349	2.683	3.295	3.272	0.251
PM	0.688	1.000	1.335	1.376	2.952	3.272	3.664	2.376	0.192
PT	0.515	0.749	1.000	1.832	1.546	2.438	2.556	2.823	0.155
MT	0.342	0.727	0.546	1.000	2.023	2.542	2.184	3.256	0.133
DS	0.299	0.339	0.647	0.494	1.000	1.336	2.223	2.286	0.089
DT	0.373	0.306	0.410	0.393	0.749	1.000	2.162	1.224	0.072
IN	0.303	0.273	0.391	0.458	0.450	0.463	1.000	1.427	0.055
SV	0.306	0.421	0.354	0.307	0.437	0.817	0.701	1.000	0.054

λ max=8.394; consistency index (CI)=0.056; and consistency ratio (CR)=0.040

The assessment of fuzzy criteria is determined by the rules of the game that are agreed upon by vendor experts which are the benchmark for assessing to maintain supply chain stability between vendors and customers for procurement of supply chain goods inventory. Of the eight criteria, there are different assessments, with the aim that supply chain availability has a very tight level of competition. This is done to guarantee the best service in the supply chain process. The assessment of fuzzy criteria that can be applied can be seen in Table 4 with the rules set. Referring to the fuzzy assessment of the criteria listed in Table 4, the dataset normalization that is owned by each vendor and has been adjusted to the type for each criterion based on (6) and (7) gives the results as shown in Table 5. The data has been calculated based on the largest value and the highest value. the smallest of each element matrices based on each criterion.

Table 3. Pairwise matrices using expert choice apps

	QG	PM	PT	MT	DS	DT	IN	SV
QG		1.453	1.943	2.923	3.349	2.683	3.295	3.272
PM			1.335	1.376	2.952	3.272	3.664	2.376
PT				1.832	1.546	2.438	2.556	2.823
MT					2.023	2.542	2.184	3.256
DS						1.336	2.223	2.286
DT							2.162	1.224
IN								1.427
SV	Incon: 0.03							

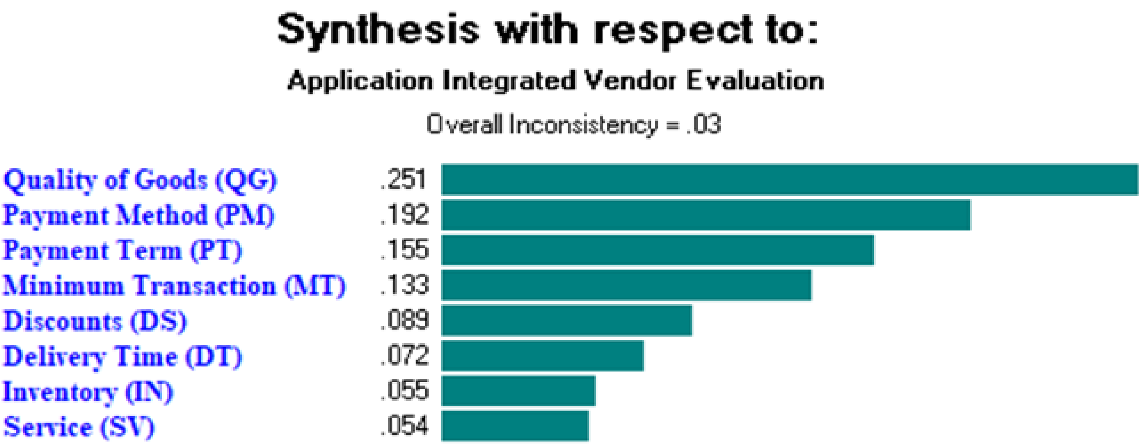

Figure 2. Synthesis of eigenvector using expert choice apps

Table 4. Fuzzy criteria

Fuzzy value	Quality of goods	Payment method (days)	Payment term (days)	Minimum transaction	Discounts	Delivery time (days)	Inventory	Services
1	Bad	Cash	≤1 days	≥5.000.000	2%	≤5	≥55%	Bad
2	Less	≤3	≥2-<7	≥3.000.000	3%	≤4	≥65%	Less
3	Enough	≤4	≥7-<14	≥1.000.000	5%	≤3	≥75%	Enough
4	Good	≤5	≥14-<21	≥500.000	7%	≤2	≥85%	Good
5	Satisfaction	>5	≤21	≥200.000	10%	≤1	≥100%	Satisfaction

Table 5. Dataset normalization

Criteria (Alt)	QG HB	PM HB	PT HB	MT (LB)	DS HB	DT (LB)	IV HB	SV HB
VD01	1.000	0.667	1.000	0.750	0.750	0.000	0.250	0.500
VD02	0.500	0.333	0.667	0.750	1.000	0.500	0.500	1.000
VD03	1.000	0.000	0.667	1.000	0.750	0.000	0.500	0.500
VD04	0.750	0.667	0.333	0.500	1.000	1.000	0.750	0.500
VD05	0.750	0.667	0.667	1.000	0.750	1.000	0.500	0.500
VD06	0.500	1.000	1.000	0.750	1.000	0.500	0.000	0.500
VD07	0.000	0.333	1.000	0.750	1.000	0.000	0.250	0.500
VD08	0.250	0.667	0.667	1.000	0.750	0.500	0.000	1.000
VD09	0.750	1.000	1.000	0.000	0.250	0.000	0.750	1.000
VD10	1.000	0.667	1.000	0.500	0.500	0.500	0.750	1.000
VD11	1.000	0.333	0.667	0.500	0.500	1.000	1.000	0.500
VD12	1.000	1.000	0.000	0.750	0.000	1.000	1.000	0.500
VD13	0.750	1.000	0.333	1.000	0.750	0.500	0.500	0.000
VD14	0.750	0.333	0.667	1.000	0.750	0.500	1.000	0.000
VD15	0.250	0.333	1.000	1.000	0.750	0.000	1.000	0.500
VD16	0.750	0.000	0.667	0.750	1.000	0.500	0.750	0.500
VD17	0.250	0.333	1.000	0.500	1.000	0.500	1.000	0.500
VD18	1.000	0.667	0.667	0.500	1.000	0.000	0.500	0.500
VD19	0.250	1.000	1.000	0.750	0.750	0.500	0.250	1.000

Pay attention to the dataset normalization in Table 5, an elimination process will be carried out for all candidate vendors to form a grouping of candidate vendors who deserve an assessment of the criteria weight through the size of their eigenvectors and the results obtained from this elimination process will be the basis for evaluating all candidate vendors for their eligibility. The basic process of eliminating candidate vendors refers to (6) and (7) and the elimination process, of course, takes into account each type of criterion it bears, either HB type which means a benefit, or LB which means cost. This type of criterion will determine the ownership of the weight value through the eigenvector that has been obtained with mathematic algebra matrices and expert choice apps. Based on the stages of this process, the final result will form a two-dimensional matrix which can be seen in Table 6 as the total result of each alternative with total ownership of the weight. Observe Table 6 on the vendor preference matrices, which is the development of 342 candidate vendors that have gone through a selection process and have been accumulated from each of the eigenvector values for each criteria calculation they have. Based on Table 6, a further evaluation and selection process will be carried out.

Table 6. Vendor preference matrices

Alt	VD 01	VD 02	VD 03	VD 04	VD 05	VD 06	VD 07	VD 08	VD 09	VD 10	VD 11	VD 12	VD 13	VD 14	VD 15	VD 16	VD 17	VD 18	VD 19
VD 01		0.24	0.18	0.20	0.11	0.14	0.31	0.25	0.21	0.06	0.17	0.22	0.19	0.20	0.25	0.24	0.29	0.08	0.19
VD 02	0.10		0.15	0.11	0.05	0.05	0.20	0.11	0.20	0.08	0.10	0.22	0.13	0.08	0.15	0.09	0.12	0.10	0.10
VD 03	0.19	0.63		0.67	0.25	0.74	1.19	0.86	0.96	0.36	0.36	0.71	0.46	0.30	0.75	0.38	1.02	0.27	0.94
VD 04	0.34	0.57	0.67		0.14	0.49	1.20	0.83	0.68	0.25	0.37	0.51	0.27	0.41	0.93	0.45	0.76	0.20	0.77
VD 05	0.33	0.65	0.53	0.42		0.57	1.28	0.68	0.86	0.43	0.55	0.71	0.28	0.32	0.84	0.59	1.03	0.41	0.76
VD 06	0.35	0.54	0.89	0.63	0.44		0.96	0.69	0.74	0.50	0.85	0.82	0.45	0.68	0.79	0.73	0.77	0.55	0.34
VD 07	0.09	0.15	0.44	0.44	0.24	0.06		0.30	0.67	0.31	0.47	0.82	0.45	0.30	0.09	0.35	0.13	0.29	0.09
VD 08	0.26	0.33	0.51	0.48	0.05	0.19	0.25		0.78	0.36	0.60	0.76	0.26	0.30	0.32	0.57	0.51	0.39	0.13
VD 09	0.36	0.90	0.78	0.50	0.40	0.42	1.25	1.01		0.19	0.59	0.61	0.47	0.65	0.94	0.78	0.94	0.46	0.61
VD 10	0.24	0.90	0.72	0.61	0.51	0.72	1.43	1.07	0.68		0.40	0.70	0.72	0.70	1.07	0.84	1.00	0.34	0.86
VD 11	0.31	0.68	0.45	0.46	0.36	0.79	1.31	1.04	0.80	0.13		0.49	0.64	0.38	0.90	0.57	0.82	0.25	0.99
VD 12	0.50	1.07	0.83	0.63	0.55	0.79	1.69	1.24	0.85	0.45	0.52		0.49	0.76	1.28	0.95	1.34	0.58	0.99
VD 13	0.45	0.77	0.65	0.46	0.19	0.49	1.40	0.80	0.78	0.55	0.74	0.56		0.38	0.96	0.71	1.15	0.53	0.69
VD 14	0.37	0.49	0.37	0.48	0.11	0.60	1.12	0.72	0.84	0.41	0.36	0.71	0.26		0.57	0.38	0.77	0.45	0.80
VD 15	0.30	0.40	0.46	0.63	0.26	0.35	0.55	0.38	0.77	0.41	0.51	0.87	0.47	0.21		0.53	0.27	0.53	0.30
VD 16	0.27	0.31	0.22	0.29	0.14	0.42	0.93	0.76	0.74	0.31	0.31	0.67	0.35	0.14	0.66		0.63	0.26	0.70
VD 17	0.33	0.26	0.62	0.36	0.35	0.22	0.49	0.46	0.66	0.23	0.33	0.82	0.56	0.30	0.16	0.40		0.34	0.25
VD 18	0.14	0.69	0.47	0.41	0.34	0.61	1.25	0.95	0.78	0.18	0.37	0.67	0.55	0.59	1.03	0.63	0.94		0.90
VD 19	0.32	0.54	0.86	0.69	0.40	0.11	0.76	0.40	0.65	0.41	0.81	0.79	0.42	0.65	0.51	0.78	0.57	0.61	

The role of the PROMETHEE method at this point will be the culmination of the selection process for selected vendors. Leaving flow and entering flow are benchmarks for the process of selecting candidate vendors and both of these can be said to be temporary decisions and not yet final. The calculation process can use (8) and (9). To determine the final decision, one more stage is needed, namely net flow, namely the final decision which can be used as a ranking system to support decision-making. The cumulative results of all syntheses can be done via (10) and can be seen in Table 7 which explains a number of vendors that are feasible and not.

Table 7. Integration decision-making of vendor evaluation

Rank	Alt	Leaving flow	Entering flow	Net flow	Decision
1	VD10	0.751	0.312	0.439	Accepted
2	VD05	0.623	0.274	0.349	Accepted
3	VD18	0.639	0.368	0.271	Accepted
4	VD13	0.681	0.413	0.268	Accepted
5	VD06	0.651	0.431	0.220	Accepted
6	VD12	0.861	0.647	0.215	Accepted
7	VD11	0.632	0.467	0.165	Accepted
8	VD14	0.546	0.407	0.138	Accepted
9	VD04	0.547	0.471	0.076	Accepted
10	VD03	0.614	0.543	0.071	Accepted
11	VD19	0.570	0.579	-0.008	Rejected
12	VD09	0.658	0.703	-0.045	Rejected
13	VD16	0.451	0.555	-0.105	Rejected
14	VD15	0.455	0.677	-0.222	Rejected
15	VD01	0.000	0.291	-0.291	Rejected
16	VD08	0.392	0.698	-0.306	Rejected
17	VD17	0.398	0.726	-0.328	Rejected
18	VD02	0.119	0.562	-0.443	Rejected
19	VD07	0.316	0.976	-0.660	Rejected

4. CONCLUSION

The findings of comprehensive research indicate that the MCDM-AHP and PROMETHEE methods offer valuable support for optimal decision-making. The procedure involves assessing and choosing nineteen potential vendors to establish a robust supply chain. This ensures that regulations are in place to ensure the availability of goods and services throughout the supply chain, encompassing selected vendors, downstream customers, and relevant agencies responsible for the selection process. It is requested that an evaluation be conducted utilizing a hierarchical rating framework. Based on the findings of his study, it is evident that certain vendors are deemed worthy of acceptance, while others are deemed unfit for acceptance. The present selection process offers decision-making assistance for evaluating and selecting outcomes that have been substantiated through the comprehensive implementation of various stages and validation methods. The findings indicate that ten vendors meet the criteria for acceptance as supply chain entities, while nine vendors do not qualify for inclusion in this category. The supply chain vendor entity with the highest rating is VD10, which achieved a score of 439. The achievement of this outcome is evident through the combined utilization of two methods, which are supported by two established optimization approaches that yield optimal outcomes for decision-making assistance.

REFERENCES

[1] Ö. Deretarla, B. Erdebilli, and M. Gündoğan, "An integrated analytic hierarchy process and complex proportional assessment for vendor selection in supply chain management," *Decision Analytics Journal*, vol. 6, no. Oct, 2023, doi: 10.1016/j.dajour.2022.100155.

[2] W. Widiasih, P. D. Karningsih, and U. Ciptomulyono, "Development of integrated model for managing risk in lean manufacturing implementation: a case study in an Indonesian manufacturing company," *Procedia Manufacturing*, vol. 4, pp. 282–290, 2015, doi: 10.1016/j.promfg.2015.11.042.

[3] M. S. Hossain, M. F. Uddin, and M. Mondal, "The effects of coordination mechanism on vendor buyer system of a supply chain," *Procedia Engineering*, vol. 194, pp. 529–536, 2017, doi: 10.1016/j.proeng.2017.08.181.

[4] S. Isanovic *et al.*, "How perspectives on food safety of vendors and consumers translate into food-choice behaviors in 6 African and Asian Countries," *Current Developments in Nutrition*, vol. 7, no. 1, 2023, doi: 10.1016/j.cdnut.2022.100015.

[5] C. Yang, K. Tian, and X. Gao, "Supply chain resilience: measure, risk assessment and strategies," *Fundamental Research*, 2023, doi: 10.1016/j.fmre.2023.03.011.

[6] V. Srivastava *et al.*, "Strengthening the immunization supply chain: A time-to-supply based approach to cold chain network optimization and extension in Madhya Pradesh," *Vaccine*, vol. 39, no. 45, pp. 6660–6670, 2021, doi: 10.1016/j.vaccine.2021.09.062.

[7] M. Sarfraz, G. Hussain, M. S. Nazir, M. I. Abdullah, and M. A. Rashid, "The moderating role of industry clockspeed on the relation between supply chain integration practices and new product flexibility," *Heliyon*, vol. 9, no. 3, 2023, doi: 10.1016/j.heliyon.2023.e14484.

[8] S. Komsiyah, R. Wongso, and S. W. Pratiwi, "Applications of the fuzzy ELECTRE method for decision support systems of cement vendor selection," *Procedia Computer Science*, vol. 157, pp. 479–488, 2019, doi: 10.1016/j.procs.2019.09.003.

[9] P. Kaur and K. N. L. Rachana, "An intutionistic fuzzy optimization approach to vendor selection problem," *Perspectives in Science*, vol. 8, pp. 348–350, 2016, doi: 10.1016/j.pisc.2016.04.071.

[10] P. K. Marhavilas, M. Filippidis, G. K. Koulinas, and D. E. Koulouriotis, "Safety-assessment by hybridizing the MCDM/AHP and HAZOP-DMRA techniques through safety's level colored maps: Implementation in a petrochemical industry," *Alexandria Engineering Journal*, vol. 61, no. 9, pp. 6959–6977, 2022, doi: 10.1016/j.aej.2021.12.040.

[11] B. M. Mohsen, "Multi-criteria decision system for the selection of a freight forwarder using AHP," *Procedia Computer Science*, vol. 220, pp. 135–144, 2023, doi: 10.1016/j.procs.2023.03.020.

[12] S. W. Chisale, S. Eliya, and J. Taulo, "Optimization and design of hybrid power system using HOMER pro and integrated CRITIC-PROMETHEE II approaches," *Green Technologies and Sustainability*, vol. 1, no. 1, 2023, doi: 10.1016/j.grets.2022.100005.

[13] J. Wątróbski, "Temporal PROMETHEE II — New multi-criteria approach to sustainable management of alternative fuels consumption," *Journal of Cleaner Production*, vol. 413, no. May, 2023, doi: 10.1016/j.jclepro.2023.137445.

[14] B. de Jonge, "Condition-based maintenance optimization based on matrix algebra," *Operations Research Letters*, vol. 49, no. 5, pp. 741–747, 2021, doi: 10.1016/j.orl.2021.08.005.

[15] J. Araújo, W. Bentz, P. J. Cameron, M. Kinyon, and J. Konieczny, "Matrix theory for independence algebras," *Linear Algebra and Its Applications*, vol. 642, pp. 221–250, 2022, doi: 10.1016/j.laa.2022.02.021.

[16] M. M. Pagliuca and D. Scarpato, "The olive oil sector: a comparison between consumers and 'experts' choices by the sensory analysis," *Procedia Economics and Finance*, vol. 17, no. 14, pp. 221–230, 2014, doi: 10.1016/s2212-5671(14)00897-1.

[17] S. A. Erdogan, J. Šaparauskas, and Z. Turskis, "Decision making in construction management: ahp and expert choice approach," *Procedia Engineering*, vol. 172, pp. 270–276, 2017, doi: 10.1016/j.proeng.2017.02.111.

[18] O. Cooper, "The magic of the analytic hierarchy process (AHP)," *International Journal of the Analytic Hierarchy Process*, vol. 9, no. 3, pp. 372–379, 2017, doi: 10.13033/ijahp.v9i3.519.

[19] A. Akmaludin, T. Hartati, H. Purwanto, T. Sukendar, F. Latifah, and L. Septiana, "The best selection of programmers in generation 4.0 using AHP and ELECTRE elimination methods," *Journal of Physics: Conference Series*, vol. 1477, no. 3, pp. 1–7, 2020, doi: 10.1088/1742-6596/1477/3/032001.

[20] A. Akmaludin, E. G. Sihombing, R. Rinawati, F. Handayanna, L. S. Dewi, and E. Arisawati, "Generation 4.0 of the programmer selection decision support system: MCDM-AHP and ELECTRE-elimination recommendations," *International Journal of Advances in Applied Sciences*, vol. 12, no. 1, pp. 48–59, 2023, doi: 10.11591/ijaas.v12.i1.pp48-59.

[21] A. Gusrialdi and Z. Qu, "Data-driven distributed algorithms for estimating eigenvalues and eigenvectors of interconnected dynamical systems," *IFAC-PapersOnLine*, vol. 53, no. 2, pp. 52–57, 2020, doi: 10.1016/j.ifacol.2020.12.048.

[22] I. Veza, S. Celar, and I. Peronja, "Competences-based comparison and ranking of industrial enterprises using PROMETHEE method," *Procedia Engineering*, vol. 100, no. January, pp. 445–449, 2015, doi: 10.1016/j.proeng.2015.01.389.

[23] J. Brodny and M. Tutak, "Assessing the energy security of European Union countries from two perspectives – a new integrated approach based on MCDM methods," *Applied Energy*, vol. 347, no. Feb, p. 121443, 2023, doi: 10.1016/j.apenergy.2023.121443.

[24] A. Sotoudeh-Anvari, "The applications of MCDM methods in COVID-19 pandemic: A state of the art review," *Applied Soft Computing*, vol. 126, 2022, doi: 10.1016/j.asoc.2022.109238.

[25] P. Kakati, "An MCDM approach based on some new pythagorean cubic fuzzy frank muirhead mean operators," *Heliyon*, vol. 8, no. 12, 2022, doi: 10.1016/j.heliyon.2022.e12249.

[26] S. French, "Reflections on 50 years of MCDM: Issues and future research needs," *EURO Journal on Decision Processes*, vol. 11, 2023, doi: 10.1016/j.ejdp.2023.100030.

[27] L. J. T. Santos *et al.*, "A variation of the diet problem: hybrid application of the AHP method and linear programming to maximize meal satisfaction in a Brazilian company," *Procedia Computer Science*, vol. 214, pp. 448–455, 2022, doi: 10.1016/j.procs.2022.11.198.

[28] D. K. Alexopoulos, A. G. Anastasiadis, S. D. Kaminaris, G. A. Vokas, and C. S. Psomopoulos, "Assessing flexibility options in power systems using fuzzy logic and AHP methods," *Energy Reports*, vol. 8, pp. 776–791, 2022, doi: 10.1016/j.egyr.2022.07.079.

[29] A. Radomska-Zalas, "The AHP method in the optimization of the epoxidation of allylic alcohols," *Procedia Computer Science*, vol. 207, pp. 456–464, 2022, doi: 10.1016/j.procs.2022.09.100.

[30] K. UmaDevi, C. Elango, and R. Rajesh, "Vendor selection using AHP," *Procedia Engineering*, vol. 38, pp. 1946–1949, 2012, doi: 10.1016/j.proeng.2012.06.237.

[31] A. Rasmussen, H. Sabic, S. Saha, and I. E. Nielsen, "Supplier selection for aerospace and defense industry through MCDM methods," *Cleaner Engineering and Technology*, vol. 12, 2023, doi: 10.1016/j.clet.2022.100590.

[32] M. Hamidah *et al.*, "Development of a protocol for malaysian important plant areas criterion weights using multi-criteria decision making - analytical hierarchy process (MCDM-AHP)," *Global Ecology and Conservation*, vol. 34, 2022, doi: 10.1016/j.gecco.2022.e02033.

[33] K. I. Abdrabo *et al.*, "An integrated indicator-based approach for constructing an urban flood vulnerability index as an urban decision-making tool using the PCA and AHP techniques: A case study of Alexandria, Egypt," *Urban Climate*, vol. 48, August 2022, 2023, doi: 10.1016/j.uclim.2023.101426.

[34] Y. Zhao and C. Deng, "Analysis of project benefit of solar energy collection and irrigation system based on AHP," *Energy Reports*, vol. 8, pp. 122–130, 2022, doi: 10.1016/j.egyr.2022.05.085.

[35] A. G. Abdullah, M. A. Shafii, S. Pramuditya, T. Setiadipura, and K. Anzhar, "Multi-criteria decision making for nuclear power plant selection using fuzzy AHP: Evidence from Indonesia," *Energy and AI*, vol. 14, no. April, 2023, doi: 10.1016/j.egyai.2023.100263.

[36] R. A. da Cunha, L. A. D. Rangel, C. A. Rudolf, and L. dos Santos, "A decision support approach employing the PROMETHEE method and risk factors for critical supply assessment in large-scale projects," *Operations Research Perspectives*, vol. 9, no. May, 2022, doi: 10.1016/j.orp.2022.100238.

[37] A. Akmaludin, C. Cahyadi, H. Kuswanto, T. Rahman, A. Sudradjatand, and E. P. Saputra, "Decision support for selection of system analyst in industry 4.0 generation erausing: MCDM-AHP and PROMETHEE elimination methods," *Asian Journal of Science and Technology*, vol. 11, no. 10, pp. 11306–11312, 2020.

[38] G. Polat, A. Damci, A. P. Gurgun, and I. Demirli, "Urban renewal project selection using the integration of AHP and PROMETHEE approaches," *Procedia Engineering*, vol. 164, pp. 339–346, 2016, doi: 10.1016/j.proeng.2016.11.628.

[39] A. El Mokrini, N. Kafa, E. Dafaoui, A. El Mhamedi, and A. Berrado, "Evaluating outsourcing risks in the pharmaceutical supply chain: case of a multi-criteria combined fuzzy AHP-PROMETHEE approach," *IFAC-PapersOnLine*, vol. 49, no. 28, pp. 114–119, 2016, doi: 10.1016/j.ifacol.2016.11.020.

[40] M. J. De Siqueira Silva *et al.*, "A comparative analysis of multicriteria methods AHP-TOPSIS-2N, PROMETHEE-SAPEVO-M1 and SAPEVO-M: selection of a truck for transport of live cargo," *Procedia Computer Science*, vol. 214, no. C, pp. 86–92, 2022, doi: 10.1016/j.procs.2022.11.152.

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