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Integrating (AHP-WPM) Approach for Optimizing Sustainable Supplier Selection

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Abstract

Sustainable supplier selection is an essential part of the decision-making process in sustainable supply chains. This choice is focusing on social, economic, and environmental criteria in evaluation of suppliers. Sustainable supplier selection approaches have used both qualitative and quantitative data. Therefore, it is meaningful to use scientific methods that treatment both quantitative and qualitative data, as well as multiple criteria. Analytical Hierarchy process (AHP) is a one of the important multi-criteria decision –making approaches. Moreover, Weighted Product Model (WPM) technique is another multi criteria scoring where in this approach, we use the multiplication instead of adding the usual in mathematical operation.

This paper aims to select the best suppliers using (AHP-WPM) approach which helps decision-makers to reach the best strategy with correct decisions. Using this approach each criterion has its assign weight, which reflects its importance for the process of comparison between alternatives to suppliers. The presented approach consists of the three main steps: the first step is to identify the criteria used in the comparison process between suppliers, the second step is to identify the decision matrix using AHP and the third step is to construct the WPM matrix and compare between the alternatives, and rank them from the best to the worst through using WPM weights. This work has used the data as in [30] which represents data for company that has four suppliers and five criteria. The results show that the best supplier is the supplier 2 which has weight equal to 0.362. In addition, our work can be extended for future work by integrating with other multi criteria approaches such as TOPSIS, MOORA, etc.

Keywords: Decision making, Sustainable Supplier Selection, AHP, WPM.

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اسلوب تكامل التحليل الهرمي ونموذج الضرب الموزون لتحسين الاختيار المستدام للموردين

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المستخلص

يعد اختيار الموردين المستدامين جزءًا أساسيًا من عملية صنع القرار في سلاسل التوريد المستدامة. يركز هذا الاختيار على المعايير الاجتماعية والاقتصادية والبيئية في تقييم الموردين. استخدمت مناهج اختيار الموردين المستدامين كلاً من البيانات النوعية والكمية. لذلك، من المفيد استخدام الأساليب العلمية التي تعالج كلاً من البيانات الكمية والنوعية، بالإضافة إلى معايير متعددة. تُعد عملية التسلسل الهرمي التحليلي (AHP)واحدة من أهم مناهج صنع القرار متعددة المعايير. علاوة على ذلك، فإن أسلوب نموذج المنتج المرجح (WPM) هو أسلوب آخر متعدد المعايير حيث نستخدم في هذا النهج الضرب بدلاً من الجمع المعتاد في العملية الرياضية. تهدف هذه الورقة إلى اختيار أفضل الموردين باستخدام نهج-AHP (WPMالذي يساعد صانعي القرار على الوصول إلى أفضل استراتيجية باتخاذ قرارات صحيحة.

باستخدام هذا النهج، يكون لكل معيار وزنه المخصص، مما يعكس أهميته لعملية المقارنة بين البدائل للموردين. يتكون النهج المقدم من ثلاث خطوات رئيسية: الخطوة الأولى هي تحديد المعايير المستخدمة في عملية المقارنة بين الموردين، والخطوة الثانية هي تحديد مصفوفة القرار باستخدام AHP والخطوة الثالثة هي بناء مصفوفة WPM والمقارنة بين البدائل، وترتيبها من الأفضل إلى الأسوأ من خلال استخدام أوزان WPM.وقد استخدم هذا العمل البيانات كما في [30] والتي تمثل بيانات لشركة لديها أربعة موردين وخمسة معايير. وتظهر النتائج أن أفضل مورد هو المورد2 الذي حقق اعلى وزن. بالإضافة إلى ذلك،

انتساب الباحثين

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معلومات البحث
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يمكن توسيع عملنا للأعمال المستقبلية من خلال التكامل مع مناهج أخرى متعددة المعايير مثل التحليل النسبي . وما إلى ذلك.

الكلمات المفتاحية: اتخاذ القرار، الاختيار المستدام للموردين، عملية التحليل الهرمي، نموذج الضرب الموزون

Introduction

In many cases choosing the right sustainable supplier isn't straightforward—it requires balancing both qualitative and quantitative factors, many of which clash. With countless options and competing priorities, businesses often turn to multi-criteria decision-making (MCDM) methods to navigate these trade-offs and find optimal solutions [1].

Over the years, researchers have relied heavily on MCDM techniques for supplier selection [2]. At its core, the goal is simple: identify suppliers that consistently meet a company's needs at a fair price. But getting there isn't easy. It demands rigorous comparisons across multiple criteria, like quality, reliability, and cost. While price matters, focusing solely on the cheapest option risks overlooking critical factors like delivery timelines or environmental impact. To tackle these complex decisions, Thomas Saaty developed the Analytic Hierarchy Process (AHP), a method that classify decisions into a hierarchy of goals, criteria, and alternatives [2].

AHP has become a go-to tool for businesses, helping them weigh priorities in manufacturing, design, and supplier selection. But it has limits—like handling only up to nine factors per decision layer. This makes it impractical for highly complex scenarios. Enter TOPSIS, another MCDM approach that sidesteps this issue by evaluating alternatives based on their proximity to an "ideal" solution and distance from a "worst-case" scenario [3]. The logic is intuitive: the best choice should align closely with the ideal (e.g., high quality, low cost) and steer clear of the undesirable (e.g., delays, hidden fees). By calculating a "closeness coefficient," TOPSIS ranks options clearly, making it a popular choice across industries.

That said, AHP isn't perfect. Its reliance on pairwise comparisons can overwhelm decision-makers, and its rigid structure struggles with interdependent criteria. To address this, the Analytic Network Process (ANP) emerged, allowing for more flexible, interconnected decision models. Recent studies, like [5], propose ways to streamline ANP's complexity, while others (e.g., [6]) combine it with SWOT analysis to enhance strategic planning.

The paper [7] determined the most suitable strategy for energy recycle using ANP technique. Application of WPM model to assist the decision maker in identifying the landmarks has been presented in [8]. The paper [9] presented the application of WPM in Selecting the best Elementary School in Indonesia. The papers [10],[11] presented other applications using WPM. AHP can be integrated with other multi criteria techniques such as DEA which is a linear programming technique, see [12],[13],[14],[15] for more details.

Many researchers have strived to develop the optimal decision-making procedures."The proposal methodology is built in such a way as to maximize the efficiency of MCDM techniques. In order to rank the alternatives according to the criteria, two different technologies, AHP and WPM, were combined. AHP approach used to structure the hierarchy and find the relative weight of the criteria, while WPM technique used to arrange supplier alternatives".

Methodology

The methodology of the paper which include the research problem, aims and the search importance is described as follows.

Research Problem

Sustainable Supplier selection is an important process for companies in order to optimize the performance of its supply chain. In addition, some multi criteria approach like the Analytic Hierarchy Process (AHP) have limitations in handling some cases. On the other hand, integrating more than multi criteria is very useful tool that helps the decision maker to reach the best decision. (AHP-WPM) is used in this study to get the best sustainable supplier selection.

Research Aims

This paper aims to obtaining the best supplier by evaluating multiple criteria using combination of two well-known multi criteria decision making approach. Also, validate the robustness and effectiveness of the presented approach by comparing the results using some available data. Moreover, to provide future direction can be extended to real word application such as the Iraqi oil industry in both deterministic and fuzzy environments and integrating with other multi criteria decision making approaches like MOORA, TOPSIS, etc.

Research Importance

This paper provides a computational approach to supplier selection using a more flexible decision-making tool using WPM and AHP. This approach is useful for real-world applications. Moreover, this paper lays the groundwork for future research in enhancing supplier selection techniques, particularly in industries with complex supply chains like oil companies, and in uncertain environments through fuzzy logic extensions.

Analytic Hierarchy Process (AHP)

It is in important tool that has used to calculate the relative weights to help the decision maker to reach the best decision. [16]. Also, AHP has used to priorities objective, weight alternatives and reach the best decision. In addition, complex problems can break down into hierarchy of simpler components using AHP. [17],[18].

The AHP basic steps are as follows:

Step 1 construct the goal, the criteria, and the alternatives of the decision problem as in Figure (1).[19,20].

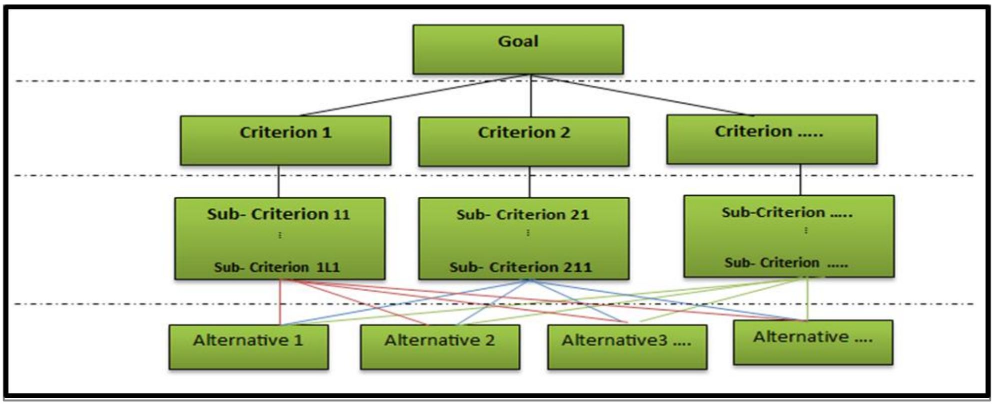

Figure (1): Generic Hierarchic Structure [21]

Step 2. Built a pairwise comparison matrix. [22],[23] as in as in equation (1) .

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1j} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2j} & \cdots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots & \vdots & \vdots \\ a_{i1} & a_{i2} & \cdots & a_{ij} & \cdots & a_{in} \\ \vdots & \vdots & \vdots & \vdots & \cdots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nj} & \cdots & a_{nn} \end{bmatrix} \quad (1)$$

where

$$a_{ij} = \frac{w_i}{w_j} \; ; i,j = 1,2,\dots,n$$

$$0 \neq a_{ij} = 1/a_{ji}$$

$$a_{ij} = 1, \; when \;\; i = j$$

The measure of the importance based on Saaty scale is described in Table (1).

Table (1): The measure of the importance

Importance	Definition	Description
1	Equality important	Two parameters has equal important
3	Moderately important	One parameter is slightly preferred over another
5	Strongly important	One parameter is strongly preferred over another
7	Very strongly important	One parameter is very strongly preferred over another
9	Extremely important	Evidence parameter one attribute is of higher preferred halfway
2,4,6,8	Intermediate values	Intermediate weights between above provision

Step 3: construct the matrix of ratio comparisons as in equation (2): as follows:

$$\begin{pmatrix} W_1/W_1 & W_1/W_2 & \cdots & W_1/W_n \\ W_2/W_1 & W_2/W_2 & \cdots & W_2/W_n \\ \vdots & \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots & \vdots \\ W_n/W_1 & W_n/W_{21} & \cdots & W_n/W_n \end{pmatrix} \begin{pmatrix} W_1 \\ W_2 \\ \vdots \\ \vdots \\ W_n \end{pmatrix} = n \begin{pmatrix} W_1 \\ W_2 \\ \vdots \\ \vdots \\ W_n \end{pmatrix} \quad (2)$$

Step 4: calculate the the relative weight using biggest eigenvalue of matrix A as in equation (3) as in [25].

$$A \times W = \lambda_{max} \times W \quad (3)$$

Step 5 : The consistency rate (CR) is calculated by equation (4) as in [15,26] as follows:

$$CR = \frac{CI}{RI} \quad (4)$$

Where ,

RI represents the random consistency index as shown in Table (2).

CI represents the consistency index and it is calculated by equation (5) as follows:

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (5)$$

Table (2): Random Index (RI) [27]

N	1	2	3	4	5	6	7	8	9	10
RI	**0**	**0**	**0.58**	**0.9**	**1.12**	**1.24**	**1.32**	**1.41**	**1.45**	**1.49**

Step 6: calculate the relative weights for all alternatives [28],[29].

Weighted Product Model (WPM)

Weighted Product Model is a one of multi criteria approach that used to score different alternatives based on number of criteria. In this approach, that decision matrix is constricted and the criteria is assigned weights. Then weights were multiplied with the corresponding performance value in the matrix for the purpose of comparison. Also, the weighted normalized decision matrix is constructed using equation (6) as in [8],[9],[10],[11] as follows:

$$A_i^{WPM} = \prod_{j=1}^{n} X_i^{W_i} \qquad (6)$$

Where,

X_i: is the performance value

W_i: is the weight of the criteria

(AHP-WPM) Computational Procedure)

We illustrate the fundamentals steps for (AHP-WPM) as following:

Step 1: Construct the model that represent the structure of the problem and determine the number of criteria and the number of alternatives.

Step 2: Pairwise comparison matrices and priority vectors performed in AHP between the criteria, pairs of decision elements at each cluster are compared with respect to their importance towards their control criteria. The relative importance values are determined with Saaty's 1–9 scale, where a score of 1 represents equal importance between the two elements and a score of nine indicates the extreme importance of one element (row cluster in the matrix) compared to the other one (column cluster in the matrix).

Step 3: Calculating the weights of criteria using AHP.

Step 4: Decision matrix is constructed using pairwise comparison in AHP between the alternatives.

Step 5: WPM decision matrix is constructed by using weighted product formula.

Step 6: Selection of the best alternatives i.e. the alternative with the largest overall priority should be selected.

Results and discussion

This work has used the data as in [30] which represents data for company that has four suppliers and five criteria.The presented approach consists of the three main steps:

1.The first step is to identify the criteria used in the comparison process between suppliers, where four suppliers denoted as (A1, A2, A3, A4) and five criteria represent (price, pollution control, due time, energy consumption, and warranty), where two criteria considered sustainable criteria (pollution control, energy consumption) and the rest economic criteria. These five criteria denoted as (C1, C2, C3, C4, C5).

2. The second step is to identify the decision matrix using AHP as shown in Table (3).

Table(3): Decision matrix and weight of criteria using AHP

Weight	0.342	0.399	0.125	0.082	0.052
	C_1	C_2	C_3	C_4	C_5
A_1	0.232	0.154	0.448	0.547	0.161
A_2	0.489	0.454	0.166	0.119	0.332

A_3	**0.182**	**0.309**	**0.200**	**0.164**	**0.416**
A_4	**0.097**	**0.084**	**0.186**	**0.170**	**0.091**

Note that Table 3, represents the weights of the criteria C1, C2, C3, C4, C5 that already obtained by AHP using pairwise comparison between the criteria and then dividing each element in the comparison matrix by the total number of each column after that we find the average of each row in the comparison matrix which represent the weight of the criteria.

3.The third step is to construct (AHP-WPM) matrix and compare between the alternatives, and rank them from the best to the worst Table 4 represents (AHP-WPM) algorithm and based on the information in Table 3 as follows:

Table(4): (AHP-WPM) Matrix

Weight	**0.342**	**0.399**	**0.125**	**0.082**	**0.052**
	C_1	C_2	C_3	C_4	C_5
A_1	$(0.232)^{0.342}$	$(0.154)^{0.399}$	$(0.448)^{0.125}$	$(0.547)^{0.082}$	$(0.161)^{0.052}$
A_2	$(0.489)^{0.342}$	$(0.454)^{0.399}$	$(0.166)^{0.125}$	$(0.119)^{0.082}$	$(0.332)^{0.052}$
A_3	$(0.182)^{0.342}$	$(0.309)^{0.399}$	$(0.200)^{0.125}$	$(0.164)^{0.082}$	$(0.416)^{0.052}$
A_4	$(0.097)^{0.342}$	$(0.084)^{0.399}$	$(0.186)^{0.125}$	$(0.170)^{0.082}$	$(0.091)^{0.052}$

Finally, Table 5, represents the final priority values of each alternative which is taken from Table (4) after multiplying each values in each row.

Table (5): Ranking of alternatives using WPM

Alternatives	Priorities	Ranking
A_1	**0.225**	**3**
A_2	**0.362**	**1**
A_3	**0.235**	**2**
A_4	**0.104**	**4**

From the final results shown in Table 5, that the best supplier is the supplier 2 which has biggest weight equal to 36.2% , then suppliers rank (supplier 3, supplier 1, supplier 4) respectively, where the worst supplier is supplier 4 which has lowest weight equal to 10.4% .

The optimal decision making is select the supplier 2 depend on Multi-Criteria (five criteria) from four suppliers Using (WPM).

Conclusions

In this paper, we present an effective multi-criteria decision-making approach for selecting the best suppliers which known as (AHP-WPM). This approach is dealing with complex decision-making scenarios compared to simpler approaches like WSM (weighted sum model). Also, WPM leads decision-makers with a more precise comparison between alternatives and a structured method for assigning weights to criteria. Moreover, the obtained decisions are robust and well informed which meet with the company's strategic objectives. Furthermore, our study shows that Supplier 2 as the best option with a weight of 0.362, indicating its superior performance relative to the other suppliers. Also, the reliability of the method used have supported by the

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