Sustainable Supplier Selection in the Manufacturing Sector Using Integrated MCDM Techniques

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Abstract. Selecting a supplier is a crucial task for any manufacturing company aiming to optimize its supply chain operations and gain a competitive advantage. The complexities of this decision-making process, influenced by various criteria and uncertainties, underscore the need for advanced methodologies such as Multi-Criteria Decision-Making (MCDM) techniques. These methodologies provide a structured framework for evaluating and prioritizing potential suppliers based on numerous criteria, often with conflicting considerations. This paper demonstrates the integration of the Analytical Hierarchy Process (AHP) and Simple Additive Weighting (SAW) through a practical example involving ten different alternatives and four distinct criteria. The alternatives are assessed and ranked for performance, utilizing systematic and objective approaches to address the inherent multi-criteria complexity of supplier selection. The strength of MCDM lies in its capability to handle both quantitative and qualitative factors, supported by decision support tools, making it a valuable asset for improving the supplier selection process.

Keywords: Analytical Hierarchy Process (AHP), Simple Additive Weighting (SAW), Multi-Criteria Decision-Making (MCDM) techniques, Supplier selection.

1 Introduction

In today's highly competitive market environment, the decision about supplier selection is very important for the success of production management [1]. MCDM techniques are essential tools for addressing complex decision problems in various domains. For many production units or manufacturing units, the issue of supplier selection problems is solved with the help of MCDM techniques [2]. MCDM techniques are used for solving problems with several alternatives and different criteria. The objective of the MCDM technique is to find the most suitable alternative among the given set of alternatives by comparing the available criteria [3], [4]. Decision-makers are required to make pair-wise comparisons between criteria and alternatives, indicating which one is the best and which one is the worst. This simplicity minimizes the cognitive burden on decision-makers and expedites the decision-making process.

MCDM is a widely embraced branch of decision theory. Despite the introduction of numerous MCDM techniques, each has its unique characteristics, and determining a singular method as the best remains intangible [5], [6]. Nevertheless, specific MCDM methods prove more suitable for particular problems. Conversely, the plethora of available MCDM methods transforms the selection process into an MCDM problem in itself [7], [8].

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1.1 Analytic Hierarchy Process (AHP)

AHP is a decision-support model created by Thomas L. Saaty at the University of Pittsburgh [9]. AHP proves effective in facilitating optimal decision-making when faced with numerous criteria [10]. The implementation of the AHP method can be as follows [11]:

1. Identify the problem, establish the solution, and construct a hierarchy of the encountered issues.
2. Establish the weight of criteria by pairwise comparisons for each criterion. This comparative process utilizes the priority scheme outlined in Table 1 [12].

Table 1. Saaty Scale

Intensity of importance	Definition
1	Equally important
3	Moderate important
5	Strongly important
7	Very strong
9	Extremely important
2, 4, 6, 8	The values between the two adjacent judgments

3. Normalize a pairwise comparison matrix is obtained by

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{i=1}^{m} a_{jk}} \quad (1)$$

4. Calculate the weight by criteria by

$$\sum Column = k_1 + k_2 + k_3 + \cdots . + k_n \quad (2)$$

5. Calculate the eigenvalues by multiplying the values in each column of the paired matrix within the same row and then raising the result to the power of the corresponding criterion number.

$$\lambda_1 = (k_1 + k_2 + k_3 + \cdots . + k_n)^{\frac{1}{n}} \quad (3)$$

6. Determine the priority weight, maximum Eigen value, and finally consistency index

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

Where: CI = Consistency Index, λ_{max} = Maximum Eigen Value, n = Number of elements

7. In the next step, to validate the results of the AHP, the consistency ratio (CR) is calculated using the formula, CR = CI/RI in which the consistency index (CI) is, in turn, measured through the following formula [13]:

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

Where: CR = Consistency Ratio, CI = Consistency Index, IR = Index Random

The value of RI is related to the dimension of the matrix and will be extracted from Table 2. It should be noted that a consistency ratio lower than 0.10 verifies that the results of the comparison are acceptable [14].

Table 2. Index Random

Matrix	1	2	3	4	5	6	7	8	9	10
IR	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

1.2 Simple Additive Weighting (SAW)

SAW is a method commonly used in Multi-Attribute Decision Making (MADM) [15]. It is also referred to as the weighted sum method [16]. The total score for an alternative is determined by summing the results by multiplying the rating and the weight assigned to each attribute [17]. The steps in utilizing the SAW method are as follows:

1. The matrix normalization is adapted based on the attribute type, generating a normalized matrix [18].

$$r_{ij} = \frac{x_{ij}}{Max(x_{ij})} \tag{6}$$

$$r_{ij} = \frac{Min(x_{ij})}{x_{ij}} \tag{7}$$

2. To calculate the weighted normalized matrix [18].

$$V_i = \sum_{j-1}^{n} = 1\ w_j r_{ij} \tag{8}$$

The weights of all criteria are determined using equation 2, and descending rankings according to the preference value of each alternative, representing the optimal outcome of the supplier assessment.

2 Literature Survey

MCDM become one of the most adapting and fastest-growing problem-solving techniques where decision-making becomes tuff under different conditions. Throughout the last decade, many scholars and experts in the field of industrial engineering have employed MCDM for decision-making. In the current literature, there is a widespread use of MCDM approaches to assist decision-makers in evaluating potential alternatives based on various criteria when dealing with the supplier selection problem. In some optimization problems, Taguchi methods are also used for the selection and optimization of alternatives [19]. Over the past two decades, methods centered on pairwise comparisons have gained broad acceptance among researchers for determining criteria weights and rankings.

Selecting suppliers and service providers through competitive bidding processes is a critical task for most operational organizations and manufacturers. In today's competitive markets, companies acknowledge the importance of meticulously choosing suppliers capable of meeting their requirements with the desired quality and within specified timeframes. In light of these conditions, organizations must effectively adjust to technological advancements, customer demands, and supplier management prerequisites to gain a competitive edge over other rivals [20]. Consequently, businesses evaluate the performance of their suppliers to identify the optimal supplier and enhance their supply chain efficiency, making supplier selection a pivotal element in the procurement process. Choosing a suitable supplier is considered non-trivial, leading decision-makers to rely on empirical evaluations predominantly.

3 Methodology

This section provides a numerical example featuring a manufacturing company aiming to choose a suitable supplier for raw material supply. The problem is addressed through the integration of the AHP and SAW methods. In this particular scenario, there are ten suppliers (A1 to A10) and four criteria (C1, C2, C3, and C4), with C1 representing the cost attribute and the rest considered benefit attributes. Initial information about the suppliers and criteria can be found in Table 6.

3.1 The Weighting Process with AHP Method

Determine the pairwise comparison matrix. At this stage, comparisons were made between the selections of criteria for private tutors using the Saaty Scale (1 to 9).

Table 3. Pairwise Comparison Matrix

	Price	Quality	Service	Delivery
Price	1	3	5	7
Quality	1/2	1	3	5
Service	1/5	1/3	1	3
Delivery	1/7	1/5	1/3	1

Determine the priority weight scale.

Table 4. Matrix of Criteria Scores and Priority Weights

	Price	Quality	Service	Delivery	Total	Priority
Price	0.5426	0.6618	0.5357	0.4375	2.178	0.5444
Quality	0.2713	0.2206	0.3214	0.3125	1.126	0.2815
Service	0.1085	0.0735	0.1071	0.1875	0.477	0.1192
Delivery	0.0775	0.0441	0.0357	0.0625	0.220	0.0550
Total	1.0000	1.0000	1.0000	1.0000	4.0000	1.0000

Determine the consistency ratio, after obtaining the weight of each criterion, the next step is to check the consistency ratio to verify the consistency of the pairwise comparisons. Summation matrices for each row are then determined by multiplying the priority weight values in Table 4 with the pairwise comparison matrix in Table 3. The calculation results are presented in Table 5.

Table 5. Consistency Ratio & Its Validation

	Total	Priority	Total / Priority	λ_{max}	CI	RI	CR=CI/RI

Price	2.3694	0.5444	4.3523	4.2031	0.0677	0.9	0.0752*
Quality	1.1860	0.2815	4.2138				
Service	0.4868	0.1192	4.0844				
Delivery	0.2288	0.0550	4.1619				
Total			16.8124				

*CR value ≤ 0.1 then the assessment is declared consistent

3.2 Alternative ranking using the SAW method

In this stage, the identification of the best supplier involves examining the initial decision matrix displayed in Table 6.

Table 6. Initial Decision Matrix

	Price	Quality	Service	Delivery
A1	9	9	9	8
A2	6	8	9	8
A3	8	6	8	9
A4	9	8	9	6
A5	8	9	9	8
A6	9	6	9	9
A7	6	6	9	6
A8	6	8	6	8
A9	8	9	6	9
A10	9	9	6	9

Identify criteria with attributes classified as either benefits or costs and then normalize the matrix. The results are obtained by multiplying the priority weights from the AHP method in Table 4 with the normalized matrix R using the SAW method, as shown in Table 7.

Table 7. Vector Calculation and Ranking of Alternatives

	Price	Quality	Service	Delivery	Vector	Rank
A1	0.0708	0.4448	0.2644	0.1641	0.9441	2
A2	0.1062	0.3954	0.2644	0.1641	0.9301	3
A3	0.0797	0.2965	0.2350	0.1846	0.7958	9
A4	0.0708	0.3954	0.2644	0.1230	0.8537	6
A5	0.0797	0.4448	0.2644	0.1641	0.9529	1
A6	0.0708	0.2965	0.2644	0.1846	0.8163	8
A7	0.1062	0.2965	0.2644	0.1230	0.7902	10
A8	0.1062	0.3954	0.1763	0.1641	0.8419	7

A9	0.0797	0.4448	0.1763	0.1846	0.8853	4
A10	0.0708	0.4448	0.1763	0.1846	0.8765	5

Finally, in the SAW method, the best alternative is A5, and then A1, A2, A9, and A10 will be respectively.

4 Discussion

This study utilizes the integration of AHP and SAW methods to enhance the decision-support process for selecting the best supplier. To improve efficiency and ease of use, simple software like MS Excel was employed. Evaluating suppliers based solely on criteria will be sufficient for future applications of the model. Implementing this evaluation via simple software will expedite the process.

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