An Empirical Study on the Development and Assessment of a Supplier Selection Model based on the Analytical Hierarchy Process in the Al Kharj Industrial Sector

Teg Alam
Department of Industrial Engineering, College of Engineering, Prince Sattam Bin Abdulaziz University, Al Kharj 11942, Saudi Arabia
t.alam@psau.edu.sa (corresponding author)

Ali AlArjani
Department of Industrial Engineering, College of Engineering, Prince Sattam Bin Abdulaziz University, Al Kharj 11942, Saudi Arabia
a.alarjani@psau.edu.sa

Received: 15 August 2024 | Revised: 9 September 2024 and 14 September 2024 | Accepted: 16 September 2024

 DOI: https://doi.org/10.48084/etasr.8746

ABSTRACT

Selecting a supplier is a critical strategic decision for supply chain management in today's global context. The process involves evaluating suppliers based on core competencies, pricing, delivery timeframes, location, data gathering, and related risks. Suppliers play a crucial role in an organization's profitability and stability. Finding the most optimal supplier can help industries reduce material expenses and maintain their competitive advantage. The supplier not only impacts the organization's profit margin but also its economic strength. Choosing a supplier requires considering qualitative and quantitative elements, making it a decision issue with several criteria. This study aims to create and evaluate a supplier selection model using the analytical hierarchy approach, focusing on a specific case study. When selecting the best supplier, it is crucial to consider tangible and intangible elements that may conflict. The supplier selection process considers several criteria, including qualitative and quantitative variables. The proposed methodology involved a literature review and informal interviews with industry experts and academics to establish the selection criteria. "Quality Supplier Corporation" was chosen due to the paramount importance of their quality. This research will comprehensively analyze several criteria to identify suppliers accurately.

Keywords-supplier selection; decision making; analytical hierarchy process; multicriteria analysis; Al Kharj

I. INTRODUCTION

In this study, the Analytical Hierarchy Process (AHP) approach is deployed to develop a supplier selection model. AHP is the most widely used methodology for supplier selection. However, it becomes very complex when many different suppliers are involved. To overcome this complexity, the weight cum rating method is utilized to initially shortlist the suppliers in this study. In this method, different weights are assigned to different criteria by the experts. The suppliers are then rated on a common scale for each criterion.

In a global environment where complexity is constantly rising, it becomes more challenging for managers of organizations, government agencies, and numerous other decision and policy makers to make optimal decisions. Over the past few years, this has also corresponded with the growth of what are now known as decision analytics approaches. In other words, decision makers are less likely to act on their gut feelings and intuition and would instead base and evaluate their decisions deploying analytical and quantitative methodologies. Many methods emerging from operation research and applied mathematics have been effective in helping decision makers make well informed decisions. A decision maker's or an expert's subjective opinions are requested as an input for several of these procedures. A practical method for decision analysis in this case is the AHP.

On the other hand, this review references a few definitions offered by Saaty, the principal inventor of the AHP, found in one of the early graduate textbooks written on this review's topic [1] to illustrate its relevance to operation research without going too far.

The AHP uses a hierarchy to achieve this, and the process is further complicated by several factors, including but not being

limited to: the goal, the available options, the set of requirements and the link between the goal, the standards, and the available choices. The complexity of real world applications has far outpaced the aforementioned case, which is designed to illustrate the AHP's core ideas. This section will briefly examine a few examples of AHP's widespread use to whet the readers' appetites for the AHP's immense potential. There are so many uses today that reviewing them all would be impossible. Even if they are not up to date, the studies conducted by authors in [2, 3] continue to be the most reliable sources.

The proposed AHP-based decision support model for supplier selection used the example of the automotive industry in Pakistan, and a sensitivity analysis was conducted to determine model's robustness [4]. Choosing a supplier was essentially a multi-criteria dilemma. It was a choice that businesses must make strategically. The nature of this decision was typically complex and unstructured. These decision making issues might receive help from management science methodologies [5]. An AHP model has been developed to address the supplier selection issue in the Turkish industry. The main Turkish producer of electromotors, Turk Electric Industries Inc. TOPEM Plant, which also serves as a supplier for a well known producer of home appliances, was then subjected to a general purpose model [6]. Information technology is necessary for businesses to make rapid, smart, and accurate purchasing decisions and manage supplier relationships more effectively. This support came from supplier selection systems and electronic procurement (e-procurement) technology [7]. Choosing and evaluating suppliers might be one of the most important tasks for an organization's success. The literature described several methods, such as the AHP and the total cost of ownership, to evaluate providers objectively [8].

In addition, one of the purchasing department's most crucial duties is supplier selection. Choosing the best supplier allowed businesses to reduce material costs and boost their competitive advantage. However, this selection becomes more difficult when there are several vendors, contradictory standards, and vague criteria [9]. The competitiveness of the entire supply chain network is significantly affected by the choice of global suppliers. In [10], the success of the supply chain appeared to be most significantly influenced by the supplier selection process [10]. Since the cost of raw materials and parts makes up most of a product's cost and most businesses must spend a sizeable portion of their revenue on purchasing, the supplier selection process has recently acquired importance [11]. An integrated, Balanced Scorecard-Fuzzy Analytical Hierarchical Process (BSC-FAHP) model was implemented in [12] to choose suppliers in the automobile industry. IN [13], an FAHP-based supplier selection model was additionally put out to offer practical insights into selecting the best suppliers in dynamic circumstances to strengthen the long term relationships with them. The manufacturing sector has been shifting toward greater value-added operations, which could significantly alter suppliers' requirements. The difficulty of choosing practical and proper suppliers is the subject of [14]. One of modern businesses' most crucial competitive strategies is Supply Chain Management (SCM). Integrating different suppliers to meet market demands is the primary goal of supply chain management [15].

Furthermore, since suppliers substantially impact a company's success or failure, success in supply starts with choosing the correct suppliers. It was ultimately directly tied to how suppliers are managed. Approaches for ranking and choosing one or more vendors from a group of suppliers are multi-criteria decisions [16]. The Fuzzy Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) and Fuzzy AHP are two methodologies studied in the literature and are recommended for use to help in supplier selection. However, there were no comparative studies of these two approaches on the issue of supplier selection [17]. Although numerous supply chain solution tools are readily available to companies in today's fast-paced business environment, choosing the right SCM software is not easy. The complexity of SCM systems creates a multifaceted issue when selecting the right software, particularly considering the speed at which technology evolves. Therefore, the AHP approach should be utilized to determine which SCM software best meets the needs of a company [18]. Being a multi-criteria problem, supplier selection involves both quantitative and qualitative standards. Authors in [19] propose adopting the AHP as a framework for wise decision making to address this issue. AHP streamlines and expedites decision making by breaking down complex circumstances into simpler parts.

One of the most significant challenges in decision making is choosing suppliers with the best chance of consistently and affordably meeting a company's needs. This is accomplished by taking into account both qualitative and quantitative considerations. A supplier's potential to meet a company's needs consistently and affordably is determined by comparing many suppliers according to a standard set of criteria and measurements. Considering the substantial reduction of purchasing costs and the enhancement of company competitiveness, selecting the correct suppliers is one of the most crucial decision making challenges [20]. Supplier selection has garnered a lot of attention in supply chain management. Thus, a collaborative purchasing program should be integrated with a supplier selection goal. After determining the weights of a selected rank, the weighted sum of the selection rank votes should be compared. Instead of using AHP's paired comparison to choose suppliers, this study proposes a novel weighting method. The voting AHP is a substitute for AHP, which offers a more straightforward approach without sacrificing the systematic procedure for determining the weights to be applied and rating suppliers' performance [21]. In [22], other methods have been adopted, such as criterion weight analysis. Evaluation weights were calculated utilizing equal weight, VNUR system weights, entropy weight, and logarithmic percentage change-driven objective weighting. The rating methods followed were the proximity-indexed value, ranking of alternatives with criteria weights, root assessment method, and simple ranking process [22].

The current study recognizes the intricate nature of supplier selection, emphasizing the need for a nuanced approach that combines quantitative methodologies with qualitative insights.

By developing an AHP-based model, this study endeavors to contribute to the advancement of supplier selection practices, ultimately aiding industries in making strategic decisions that align with their objectives and enhance overall competitiveness. This study aims to result in an enhanced methodology that employs the AHP to determine the global and local criterion weights, thereby selecting the most suitable supplier. The specific objectives of this study are:

- To find out the various criteria for supplier selection.
- To evaluate the identified criteria.
- To prioritize the various suppliers.
- To develop a model for supplier selection.

II. MATERIALS AND METHODS

This study adopted the AHP to determine the supplier selection. Choosing a supplier is challenging since it involves making decisions based on several criteria, which requires considering a great deal of information. The first step with which this process begins is to determine the characteristics of the native suppliers. Figures 1 and 2 present flowcharts illustrating the methods that affected the criteria establishment.

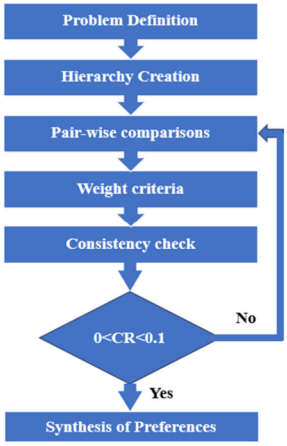

Fig. 1. AHP flowchart.

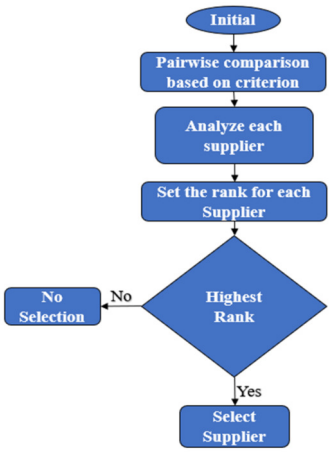

Fig. 2. Supplier selection flowchart.

A. *Steps in Supplier Selection*

Step 1. Determination of the problem and hierarchy establishment. The decision-making problem is established and a hierarchical structure is built, with the primary aim (goal) placed at the top, and the sub-goals (criteria) and possibilities (alternatives) at the lower levels.

Step 2. Pairwise comparisons. The pairwise comparison matrix is constructed according to the rules of Table I.

TABLE I. SATTY RATING SCALE

Importance intensity	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective.
3	Somewhat more important	Experience and judgement slightly favor one over the other.
5	Much more important	Experience and judgement strongly favor one over the other.
7	Very much more important	Experience and judgement very strongly favor one over the other. Its importance is demonstrated in practice.
9	Absolutely more important	The evidence favoring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed.

Step 3. Determination of the weights of the criteria. The AHP algorithm calculates the weight of each criterion. The criteria are prioritized according to their significance for a final decision to be made while comparing alternatives.

Step 4. Evaluation of each option's relative importance. The highlighted selection criteria will be used to compare the alternatives. Ultimately, this will produce a new set of pairwise comparison matrices that include the same criteria. The AHP algorithm will be executed after the matrices are completed. AHP's consistency check, as evidenced in Table II, ensures logical and consistent pairwise comparisons. Mistakes in decision-making might result from inconsistent judgments. If discrepancies are found, these judgments may have to be adjusted until everything is consistent.

TABLE II. RANDOM CONSISTENCY INDEX

Dimension	Random Index
1	0
2	0
3	0.58
4	0.9
5	1.12
6	1.24
7	1.32
8	1.41
9	1.45
10	1.49
11	1.51
12	1.48
13	1.56
14	1.57
15	1.59

Step 5. Establishing preferences. The options are evaluated and ranked using the computed weights. A combined score is

then generated for each option, considering the relative importance of the criteria and how well each of these options performed regarding these criteria. The optimal outcome would be to select the most excellent synthesized score option.

Step 6. Sensitivity analysis. Decision makers may evaluate the potential effects of shifting the criteria weights or adjusting their judgments deploying sensitivity analysis made possible by AHP.

Step 7. Making a final decision. Based on the prioritized criteria and the synthesized scores, the options should be ranked or a final choice should be made.

B. Supplier Selection

Decisions about supplier selection are frequently seen as among the most important duties in supply chain management [23]. Organizations should consider environmental concerns and adopt the supplier selection assessment methodology to maintain a competitive edge in international marketplaces. Supplier selection decisions can be made in a variety of circumstances, including several supplier cases and different product life cycle stages ranging from the original raw material purchase to the termination of the service provider [24].

1) Proposed Criteria Description

It is critical for businesses to select suitable suppliers to meet their needs and contribute to their success. This paper will develop a framework for the selection of suppliers based on the following criteria:

1. Quality: It refers to the level of excellence and conformance to specifications that should be accomplished by the products or services provided by a supplier. It encompasses reliability, durability, consistency, and the absence of defects or deviations from agreed-upon standards.
2. Delivery: Delivery criteria assess a supplier's ability to meet agreed upon delivery schedules and lead times. The term involves shipments' timeliness, accuracy, and reliability to ensure that products or services are received when needed.
3. Performance History (PH): It evaluates a supplier's past performance and track record regarding quality, on-time delivery, and agreement adherence. It involves assessing the supplier's reliability and consistency in meeting expectations.
4. Price: Price criterion considers the cost of products or services the supplier provides. It involves comparing the pricing structure to ascertain that it is competitive and responds to the value of the quality and features offered.
5. Attitude: Attitude assesses the supplier's willingness and attitude towards collaboration and problem solving. A positive attitude and the commitment to address issues can enhance the working relationship.
6. Location: The supplier's proximity is considered. Based on the buyer's needs, it may influence logistics, lead times, shipping costs, and the environment. Organizations may use these variables to pick suppliers that respond to their needs, objectives, and quality standards.
7. Climate: It refers to the prevailing weather and environmental conditions of a region where suppliers operate their facilities or conduct their business activities.
8. Rule of Government (RG): It refers to the legal and regulatory framework established by the government of a country or region, where a supplier operates.
9. Special Services (SS): SS, such as maintaining equipment, replacing damaged items, providing use instructions, and the associated services, may influence supplier selection.
10. Flexibility: The ability of a supplier to adapt to the changes in demand and order design, as well as their flexibility in providing quality responses, might be crucial considerations when choosing a supplier.
11. Terms of Payment (TP): TP consider convenience, manner, and due date. Successful business negotiations need a vendor-customer agreement, which varies per vendor, and a vendor-customer relationship.
12. Lead Time (LT): Represents the interval between the order and the delivery of goods. The time it takes for customers to receive their products significantly impacts an organization's basic operations.
13. Discounts and Freight (DF): The consumer bears the additional expense of delivery-related costs, such as shipping, customs, and storage. This cost could vary from one vendor to another. Additionally, reductions offered in terms of payment or the amount of purchased goods can result in significant savings for the clients.
14. Financial Strength (FS): Knowing the vendor's financial standing can help determine how much they can offer and how flexible the payment terms are. It will also provide an update on the partnership's sustainability.
15. Risk Management (RM): It identifies and mitigates potential risks associated with the supplier, such as geopolitical, supply chain, or natural disaster-related risks.
16. Capacity to Handle Surges in Demand (CHSD): The supplier's ability to accommodate surges in orders is critical for businesses with seasonal or fluctuating demand.

2) Supplier Description

The eight considered suppliers, each evaluated based on the developed criteria, are:

A) Quality Supplier Corporation

B) Accredited Logistics, Inc.

C) Reliable Manufacturing, Co.

D) Procurement Services, Inc.

E) Eco-Conscious Solutions, Inc.

F) Producing Systems Inc.

G) Cutting-Edge Tech Company

H) Value-driven Suppliers, Inc.

Table III summarizes the criteria description for these suppliers.

3) Supplier Selection Model

By using (1), it is easy to calculate the utility scores for each alternative. The utility score represents the overall value or desirability of each alternative, considering all criteria. This can be done by aggregating weighted scores for each criterion using a chosen utility function or aggregation method. The developed Multi-Criteria Utility Function (MCUF) is:

$$MCUF_{S_i} = \alpha_1 * [Q] + \alpha_2 * [D] + \alpha_3 * [P\ H] + \alpha_4 * [P] + \alpha_5 * [At] + \alpha_6 * [L] + \alpha_7 * [C] + \alpha_8 * [RG] + \alpha_9 * [SS] + \alpha_{10} * [Fle] + \alpha_{11} * [TP] + \alpha_{12} * [LT] + \alpha_{13} * [DF] + \alpha_{14} * [FS] + \alpha_{15} * [RM] + \alpha_{16} * [CHSD] \quad (1)$$

where:

S_i : Suppliers (i= 1, 2, …..., 8)

α_1: Weight of quality

α_2: Weight of delivery

α_3: Weight of PH

α_4: Weight of price

α_5: Weight of attitude

α_6: Weight of location

α_7: Weight of climate

α_8: Weight of RG

α_9: Weight of SS

α_{10}: Weight of flexibility

α_{11}: Weight of TP

α_{12}: Weight of LT

α_{13}: Weight of DF

α_{14}: Weight of FS

α_{15}: Weight of RM

α_{16}: Weight of CHSD

Q: Pairwise comparisons of quality options

D: Pairwise comparisons of delivery options

PR: Pairwise comparisons of PH options

P: Pairwise comparisons of price options

At: Pairwise comparisons of attitude options

L: Pairwise comparisons of location options

C: Pairwise comparisons of climate options

RG: Pairwise comparisons of RG options

SS: Pairwise comparisons of SS options

Fle: Pairwise comparisons of flexibility options

TP: Pairwise comparisons of TP options

LT: Pairwise comparisons of LT options

DF: Pairwise comparisons of DF options

FS: Pairwise comparisons of FS options

RM: Pairwise comparisons of RM options

CHSD: Pairwise comparisons of CHSD options

The above model was utilized for all criteria and suppliers.

TABLE III. SUPPLIER PRIORITY BASED ON EACH CRITERION

Supplier	Quality	Delivery	PH	Price	Attitude	Location	Climate	RG	SS	Flexibility	TP	LT	DF	FS	RM	CHSD
A	0.30	0.27	0.24	0.22	0.12	0.15	0.17	0.21	0.23	0.25	0.16	0.24	0.25	0.07	0.16	0.13
B	0.16	0.19	0.09	0.09	0.07	0.27	0.18	0.06	0.21	0.15	0.07	0.19	0.16	0.16	0.05	0.07
C	0.10	0.14	0.18	0.16	0.08	0.07	0.05	0.07	0.12	0.25	0.08	0.12	0.18	0.05	0.06	0.05
D	0.10	0.14	0.12	0.15	0.21	0.05	0.06	0.14	0.13	0.07	0.19	0.04	0.13	0.27	0.06	0.14
E	0.14	0.06	0.06	0.11	0.09	0.15	0.11	0.19	0.08	0.11	0.15	0.19	0.06	0.07	0.26	0.13
F	0.08	0.05	0.04	0.07	0.06	0.16	0.09	0.08	0.06	0.05	0.10	0.06	0.07	0.16	0.16	0.17
G	0.07	0.10	0.20	0.11	0.25	0.07	0.23	0.13	0.13	0.07	0.21	0.10	0.05	0.11	0.12	0.22
H	0.05	0.06	0.07	0.11	0.14	0.07	0.11	0.12	0.06	0.05	0.05	0.07	0.09	0.11	0.14	0.09
CR =	0.05	0.04	0.03	0.06	0.03	0.08	0.06	0.07	0.09	0.05	0.04	0.09	0.07	0.07	0.09	0.08

III. RESULTS AND ANALYSIS

The problem's objective is represented at the top of the hierarchy, and the 16 primary factors for selecting suppliers make up the second level. Table IV displays the pairwise comparison matrix for the first level of the model. Table V and Figure 3 depict that Quality is the most important factor, scoring 17.0%, with the other factors following. This analysis suggests that when choosing a supplier, the most significant weight should be the product quality that the supplier will offer and that the buyer (i.e., company) will receive. If raw materials are available, the quality of the finished product can be significantly influenced through the latter's employment.

The final priority value for the supplier selection process is determined by multiplying the weight of each criterion by the supplier rating for each criterion, and then summing it up for all requirements. This straightforward computation reveals the alternative supplier with the highest final value.

TABLE IV. PAIR-WISE COMPARISON MATRIX (FIRST LEVEL)

	Quality	**Delivery**	**PH**	**Price**	**Attitude**	**Location**	**Climate**	**RG**	**SS**	**Flexibility**	**TP**	**LT**	**DF**	**FS**	**RM**	**CHSD**	**Priority**
Quality	1.00	3.00	5.00	2.00	7.00	4.00	3.00	7.00	4.00	7.00	4.00	2.00	1.00	7.00	3.00	3.00	0.170
Delivery	0.33	1.00	3.00	0.50	3.00	4.00	6.00	3.00	3.00	4.00	2.00	2.00	0.50	3.00	2.00	5.00	0.099
PH	0.20	0.33	1.00	0.20	3.00	0.50	7.00	2.00	3.00	2.00	0.50	3.00	0.20	2.00	2.00	6.00	0.068
Price	0.50	2.00	5.00	1.00	7.00	5.00	2.00	2.00	2.00	3.00	2.00	3.00	2.00	2.00	3.00	4.00	0.124
Attitude	0.14	0.33	0.33	0.14	1.00	0.50	3.00	0.50	2.00	3.00	0.50	1.00	0.25	0.50	0.50	2.00	0.034
Location	0.25	0.25	2.00	0.20	2.00	1.00	1.00	1.00	2.00	2.00	0.50	1.00	0.50	2.00	1.00	2.00	0.045
Climate	0.33	0.17	0.14	0.50	0.33	1.00	1.00	1.00	1.00	1.00	0.50	0.50	0.25	0.50	0.50	0.50	0.027
RG	0.14	0.33	0.50	0.50	2.00	1.00	1.00	1.00	2.00	2.00	0.50	2.00	0.33	1.00	0.50	1.00	0.038
SS	0.25	0.33	0.33	0.50	0.50	0.50	1.00	0.50	1.00	1.00	0.50	0.50	0.25	0.50	0.33	0.50	0.025
Flexibility	0.14	0.25	0.50	0.33	0.33	0.50	1.00	0.50	1.00	1.00	0.33	0.50	0.20	0.50	0.33	0.33	0.021
TP	0.25	0.50	2.00	0.50	2.00	2.00	2.00	2.00	2.00	3.00	1.00	4.00	0.50	2.00	2.00	2.00	0.068
LT	0.50	0.50	0.33	0.33	1.00	1.00	2.00	0.50	2.00	2.00	0.25	1.00	0.25	0.50	0.50	1.00	0.035
DF	1.00	2.00	5.00	0.50	4.00	2.00	4.00	3.00	4.00	5.00	2.00	4.00	1.00	3.00	3.00	4.00	0.122
FS	0.14	0.33	0.50	0.50	2.00	0.50	2.00	1.00	2.00	2.00	0.50	2.00	0.33	1.00	1.00	2.00	0.042
RM	0.33	0.50	0.50	0.33	2.00	1.00	2.00	2.00	3.00	3.00	0.50	2.00	0.33	1.00	1.00	2.00	0.050
CHSD	0.33	0.20	0.17	0.25	0.50	0.50	2.00	1.00	2.00	3.00	0.50	1.00	0.25	0.50	0.50	1.00	0.032
CR =	0.06																

TABLE V. NORMALIZED WEIGHT OF THE CRITERIA

S. No.	**Criteria**	**Priorities**	**Weight (100%)**	**Rank**
C1	Quality	0.170	17.0	1
C2	Delivery	0.099	9.9	4
C3	Performance History	0.068	6.8	5
C4	Price	0.124	12.4	2
C5	Attitude	0.034	3.4	12
C6	Location	0.045	4.5	8
C7	Climate	0.027	2.7	14
C8	Rule of government	0.038	3.8	10
C9	Special services	0.025	2.5	15
C10	Flexibility	0.021	2.1	16
C11	Terms of payment	0.068	6.8	6
C12	Lead time	0.035	3.5	11
C13	Discounts and freight	0.122	12.2	4
C14	Financial strength	0.042	4.2	9
C15	Risk management	0.050	5.0	7
C16	Capacity to handle surges in demand	0.032	3.2	13

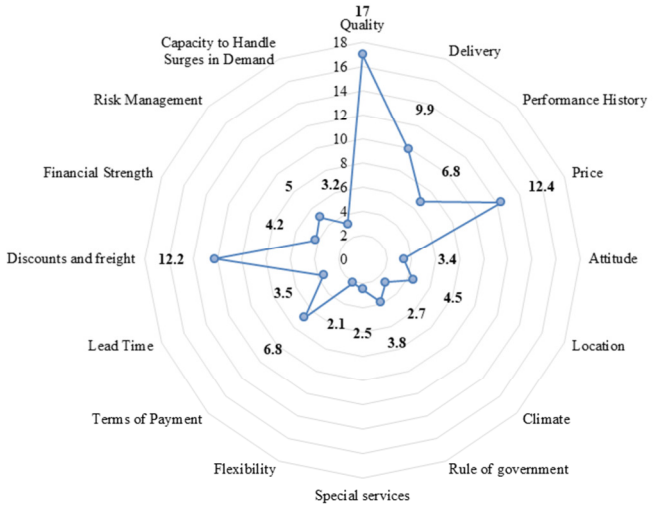

Fig. 3. Normalized weight of the criteria.

Table VI showcases the ranking of suppliers in order of importance. It is demonstrated that, out of the sixteen criteria, supplier A was considered the best and had the greatest impact on the result. Based on these findings, it is strongly recommended that the business choose this supplier.

TABLE VI. SUPPLIER PRIORITY RANKING

	Supplier name	**Priority**	**Rank**
A	Quality Supplier Corporation	0.2200	1
B	Accredited Logistics, Inc.	0.1340	2
D	Procurement Services, Inc.	0.1270	3
C	Reliable Manufacturing, Co.	0.1200	4
G	Cutting-Edge Tech Company	0.1190	5
E	Eco-Conscious Solutions, Inc.	0.1160	6
F	Producing Systems Inc.	0.0850	7
H	Value-driven Suppliers, Inc.	0.0790	8

IV. CONCLUSIONS

This research identifies the essential factors for selecting suppliers to a firm. A total of 16 factors were established in an attempt to assist organizations in making impartial judgments. The research identified the crucial factors that indigenous supplier businesses must take into account to ensure their significance in a competitive business landscape. The Analytic Hierarchy Process (AHP) is a system designed to provide an unbiased framework for selecting suppliers, and it plays a crucial part in this process. The study highlights the efficacy of the approach in managing challenging business choices and specifically examines supplier selection via the use of the AHP. This framework is not just a tool but a strategic enabler, aiming to enhance industries' strategic decision making and competitiveness by using quantitative methodologies and qualitative perspectives to facilitate the supplier selection processes. An AHP-based model for supplier selection has been developed along with the criteria for supplier assessment and ranking. In conclusion, the AHP is a versatile and efficient tool that successfully connects subjective judgments with numerical evaluations in several decision making domains. Its proved applicability and methodical approach make it essential for firms navigating complex decision landscapes.

FUNDING

This project was funded by the Deanship of Scientific Research at Prince Sattam bin Abdulaziz University, project number (PSAU/2024/01/28641).

ACKNOWLEDGMENT

The authors extend their appreciation to Prince Sattam bin Abdulaziz University for funding this research work through project number (PSAU/2024/01/28641).

REFERENCES

[1] T. L. Saaty, "Some thoughts on creativity," in *Mathematical methods of operations research*, New York, NY, USA: Dover Publications, 1959, pp. 381–399.

[2] B. L. Golden, E. A. Wasil, and D. E. Levy, "Applications of the Analytic Hierarchy Process: A Categorized, Annotated Bibliography," in *The Analytic Hierarchy Process: Applications and Studies*, B. L. Golden, E. A. Wasil, and P. T. Harker, Eds. New York, NY, USA: Springer, 1989, pp. 37–58.

[3] L. G. Vargas, "An overview of the analytic hierarchy process and its applications," *European Journal of Operational Research*, vol. 48, no. 1, pp. 2–8, Sep. 1990, https://doi.org/10.1016/0377-2217(90)90056-H.

[4] F. Dweiri, S. Kumar, S. A. Khan, and V. Jain, "Designing an integrated AHP based decision support system for supplier selection in automotive industry," *Expert Systems with Applications*, vol. 62, pp. 273–283, Nov. 2016, https://doi.org/10.1016/j.eswa.2016.06.030.

[5] C. Kahraman, U. Cebeci, and Z. Ulukan, "Multi-criteria supplier selection using fuzzy AHP," *Logistics Information Management*, vol. 16, no. 6, pp. 382–394, Jan. 2003, https://doi.org/10.1108/09576050310503367.

[6] G. Barbarosoglu and A. T. Aktin, "An Application of the Analytic Hierarchy Process to the Supplier Selection Problem," *Production and Inventory Management Journal*, vol. 38, no. 1, pp. 14–21, 1997.

[7] M. Benyoucef and M. Canbolat, "Fuzzy AHP-based supplier selection in e-procurement," *International Journal of Services and Operations Management*, vol. 3, no. 2, pp. 172–192, Jan. 2007, https://doi.org/10.1504/IJSOM.2007.012136.

[8] K. S. Bhutta and F. Huq, "Supplier selection problem: a comparison of the total cost of ownership and analytic hierarchy process approaches," *Supply Chain Management: An International Journal*, vol. 7, no. 3, pp. 126–135, Jan. 2002, https://doi.org/10.1108/13598540210436586.

[9] M. B. Ayhan, "A Fuzzy AHP Approach for Supplier Selection Problem: A Case Study in a Gear Motor Company." arXiv, Oct. 09, 2013, https://doi.org/10.48550/arXiv.1311.2886.

[10] F. T. S. Chan, N. Kumar, M. K. Tiwari, H. C. W. Lau, and K. L. Choy, "Global supplier selection: a fuzzy-AHP approach," *International Journal of Production Research*, vol. 46, no. 14, pp. 3825–3857, Jul. 2008, https://doi.org/10.1080/00207540600787200.

[11] O. Kilincci and S. A. Onal, "Fuzzy AHP approach for supplier selection in a washing machine company," *Expert Systems with Applications*, vol. 38, no. 8, pp. 9656–9664, Aug. 2011, https://doi.org/10.1016/j.eswa.2011.01.159.

[12] M. R. Galankashi, S. A. Helmi, and P. Hashemzahi, "Supplier selection in automobile industry: A mixed balanced scorecard–fuzzy AHP approach," *Alexandria Engineering Journal*, vol. 55, no. 1, pp. 93–100, Mar. 2016, https://doi.org/10.1016/j.aej.2016.01.005.

[13] V. Yadav and M. K. Sharma, "Multi-criteria decision making for supplier selection using fuzzy AHP approach," *Benchmarking: An International Journal*, vol. 22, no. 6, pp. 1158–1174, Jan. 2015, https://doi.org/10.1108/BIJ-04-2014-0036.

[14] R. Jain, A. R. Singh, and P. K. Mishra, "Prioritization of Supplier Selection Criteria: A Fuzzy-AHP Approach," *MIT International Journal of Mechanical Engineering*, vol. 3, no. 1, pp. 34–42, 2013.

[15] H. S. Tooranloo and A. Iranpour, "Supplier selection and evaluation using interval-valued intuitionistic fuzzy AHP method," *International Journal of Procurement Management*, vol. 10, no. 5, pp. 539–554, Jan. 2017, https://doi.org/10.1504/IJPM.2017.086399.

[16] P. Shafi Salimi and S. A. Edalatpanah, "Supplier selection using fuzzy AHP method and D-numbers," *Journal of Fuzzy Extension and Applications*, vol. 1, no. 1, pp. 1–14, Mar. 2020, https://doi.org/10.22105/jfea.2020.248437.1007.

[17] F. R. Lima Junior, L. Osiro, and L. C. R. Carpinetti, "A comparison between Fuzzy AHP and Fuzzy TOPSIS methods to supplier selection," *Applied Soft Computing*, vol. 21, pp. 194–209, Aug. 2014, https://doi.org/10.1016/j.asoc.2014.03.014.

[18] Z. Wang, R. Yan, K. Hollister, and R. Xing, "A Relative Comparison of Leading Supply Chain Management Software Packages," *International Journal of Information Systems and Supply Chain Management*, vol. 2, no. 1, pp. 81–96, Jan. 2009, https://doi.org/10.4018/jisscm.2009010106.

[19] R. Hruska, P. Prusa, and D. Babic, "The use of AHP method for selection of supplier," *Transport*, vol. 29, no. 2, pp. 195–203, Apr. 2014, https://doi.org/10.3846/16484142.2014.930928.

[20] O. Kilincci and S. A. Onal, "Fuzzy AHP approach for supplier selection in a washing machine company," *Expert Systems with Applications*, vol. 38, no. 8, pp. 9656–9664, Aug. 2011, https://doi.org/10.1016/j.eswa.2011.01.159.

[21] F.-H. F. Liu and H. L. Hai, "The voting analytic hierarchy process method for selecting supplier," *International Journal of Production Economics*, vol. 97, no. 3, pp. 308–317, Sep. 2005, https://doi.org/10.1016/j.ijpe.2004.09.005.

[22] D. T. Do, "Assessing the Impact of Criterion Weights on the Ranking of the Top Ten Universities in Vietnam," *Engineering, Technology & Applied Science Research*, vol. 14, no. 4, pp. 14899–14903, Aug. 2024, https://doi.org/10.48084/etasr.7607.

[23] D. Golmohammadi and M. Mellat-Parast, "Developing a grey-based decision-making model for supplier selection," *International Journal of Production Economics*, vol. 137, no. 2, pp. 191–200, Jun. 2012, https://doi.org/10.1016/j.ijpe.2012.01.025.

[24] C. Bai and J. Sarkis, "Integrating sustainability into supplier selection with grey system and rough set methodologies," *International Journal of Production Economics*, vol. 124, no. 1, pp. 252–264, Mar. 2010, https://doi.org/10.1016/j.ijpe.2009.11.023.