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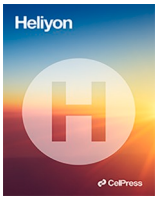

Addressing the supplier selection problem by using the analytical hierarchy process

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A R T I C L E I N F O

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Analytical hierarchy process
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A B S T R A C T

ACI Pharma spends $ 12 to 15 million yearly to promote its brands. The brand promotional activities of the company were hampered, due to supplier selection subjectively, which impacted market share. The study selects the best supplier with supplier management and purchasing policy for printing materials for ACI Pharma based on objective judgments. The required data has been collected from the company. This study uses the Analytical Hierarchy Process (AHP) to address supplier selection and management problems. Five attributes, cost, quality, delivery, flexibility, and communication, and ten suppliers have been evaluated to select the best supplier. Spark Printers is the best supplier for ACI Pharma as it obtains the highest score, 0.968, whereas Marvelous Printers Limited and Lutfur Enterprise are the second-best and third-best suppliers. The application of AHP in the pharmaceutical supply chain industry is very limited. Further, Previous studies emphasized supplier selection rather than management and purchasing policy. Moreover, industry practitioners, especially in developing countries, might not use complex methodologies due to time, money, or technical constraints. Considering these thoughts, this study is conducted to select and manage the right supplier with purchasing policy using AHP in industry-friendly language and analysis patterns. Other organizations suffering from similar problems, such as ACI Pharma, may benefit from this research. The study has selected AHP, purposively, without any methodological justifications, although many Multi-Criteria Decision-Making (MCDM) techniques are present. Further studies might be conducted to find which MCDM method fits best to address the supplier selection problem in the pharmaceutical supply chain industry.

1. Introduction

By population, Bangladesh is the fifth and eighth largest country in Asia and the world, respectively. The economy of Bangladesh is shifting to the industrial sector [1]. The pharmaceutical industry of Bangladesh is contributing a significant role in its economic development and worldwide health security by exporting its drug. The pharma industry is supplying medicine to over 100 countries [2]. ACI (Advanced Chemical Industries) Limited is a Bangladesh-based multinational company operating 42 businesses worldwide. ACI Pharma, one of the most priority businesses of ACI, is exporting pharmaceutical products to 30 countries on 4 continents and contributing to world health security by introducing innovative and reliable pharmaceutical products [3]. In Bangladesh, ACI Pharma is one of the leading pharmaceutical manufacturers holding a 3%–4% share of the pharma industry [4,5]. Doctors are the core customers of any pharmaceutical company because people purchase drugs according to the prescription provided by the doctor. In Bangladesh, companies use various printing materials, drug samples, and gifts to promote its product to doctors [6].

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Printing materials include literature, showcard, call cards, drop cards, spiral pads, note pads, calendars, journal reports, medical books, notebooks, posters, banners, stickers, and similar things carries different scientific information regarding a specific drug of a company. One of the primary roles of the supply chain department of ACI Pharma is to procure printing materials from different suppliers for the marketing team so that marketing personnel can do smooth brand promotion. Procurement is one of the most vital tasks of the supply chain department affecting various aspects of organizational competence [7]. To meet organizational needs, supplier relationships should be maintained in the procurement process [8]. Purchase items might classify as routine, leverage, bottleneck, and critical based on the strategic importance, purchased volume, percentage of total purchasing cost, impact on the product, supply risk, number of supplies, availability, and storage risks [9]. A specific item may be a routine or leverage based on the type of the company. A company has higher strategic importance with lower supply risk for leverage items, so a firm can optimize its gain through contracts with suppliers. Before a contract and negotiation, Decision Maker (DM) should find a good supplier. Who is a good supplier of printing materials? Finding a good supplier is one of the main problems for ACI Pharma.

The supplier selection procedure involves different tangible criteria and intangible criteria. The most important criteria for supplier evaluation include price, quality, and delivery time [10]. Organizations used to select its supplier based on Economic criteria avoiding the social and environmental issues in the old time. In the present sustainable era, many organizations choose suppliers based on three dimensions of sustainability, economic, social, and environmental issues. Quality, delivery, and price are the most economic criteria for supplier selection problems [11]. The supplier selection problem considers economic, environmental, and social concerns [12]. Supplier selection is one of the most prominent issues for a sustainable business, and the adverse environmental history, cost, quality, service, and environmental initiatives are the top attributes for electric vehicle supplier selection [13]. However, different organizations have different criteria for supplier selection problems based on the characteristics of organizations.

A company invests a lot of time and money in purchasing promotional materials. ACI Pharma spends $ 12 to 15 million yearly to promote its brands to customers. The company purchases printing materials from 25 suppliers. Supplier claims superiority in price, quality, delivery time, flexibility, and communication. ACI Pharma selects its suppliers based on subjective judgment rather than objective. After a successful purchase deal, in most cases, suppliers violate the pre-purchasing statement regarding price, quality, and delivery time to make more profit. Finally, the promotional activities of the company are hampered, and the company loses market share and profit significantly. What is the solution? The management of ACI Pharma has realized the importance of supplier selection based on objective judgment rather than subjective, but the right supplier selection is not easy. The exercise of structured decision-making criteria is necessary for selecting a good supplier, especially under a complex situation involving quantitative and qualitative criteria [14].

Over the last two decades, decision-making theories have been rigorously used for supplier selection problems [15]. The application of the Multi-Criteria Decision-Making (MCDM) technique to select a sustainable supplier is improving [16]. The MCDM method is used for best supplier selection due to the appearance of subjective judgment, various criteria, risk, and qualitative variables [17]. Most of the research has been focused on the development and improvement of the new MCDM method, while relatively limited attention has been given to the proper method selection and practical implementation, but the MCDM technique may provide the inconsistent result due to a lack of correct method selection [18]. Although there are many MCDM techniques, the Analytical Hierarchy Process (AHP) is the most exercisable method for the decision-making problem [19]. An advantage of the AHP technique is allowing both qualitative and quantitative criteria for comparison [20]. The AHP method has been used to select the vendor and supplier [21]. The AHP algorithm has been used to identify and quantify the factors affecting flood hazards [22]. The sustainable supply chain has been developed in the renewable energy sector using the AHP method incorporating the social, economic, and environmental dimensions [23].

The author reviewed 68 articles on the AHP and MCDM method from 2008 to 2023 and found most articles dealt with theoretical development rather than practical application in industry. Further, the author has not found an article that dealt with the supplier selection problem in the pharmaceutical industry meaning there is either zero application or very limited application of AHP in the pharmaceutical supply chain industry. There are very limited applications of the AHP in the healthcare supply chain industry in terms of relevance and priority [24]. Every industry has specific characteristics means the food, energy, and pharmaceutical industry have different challenges and solutions in the supply chain, production, and marketing. Purchasing technique and supplier management policy are the other parts of the supply chain like supplier selection, but previous studies emphasized supplier selection rather than supplier management by the AHP method. Moreover, in a developing country like Bangladesh, industry practitioners may not be interested in applying a complex form of method to make business decisions due to time, money, or technical constraints. The objective of this study is the right supplier selection and management along with guidelines for purchasing techniques for the printing materials of ACI Pharma using the AHP method in industry-friendly language and analysis patterns. This study emphasizes the application side of AHP rather than the theoretical development. This research work would help the management of ACI Pharma to choose the best supplier and suggest the purchasing policy with supplier management techniques for printing materials. Other organizations suffering from the problem of supplier selection and management may benefit from this research.

2. Methodology

MCDM technique aims to guide the DM in discovering the most desired solution to the problem. The MCDM is a choice of the best option from available options [25]. The MCDM techniques, for example, the Analytical Hierarchy Process, Analytic Network Process (ANP), Quality Function Deployment (QFD), and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), have been widely used in sustainable supplier selection problems [26]. The AHP is the most used MCDM technique to select the best option from available alternatives [27]. To choose the best irrigation system, the AHP method has been applied [28]. The AHP is an attractive

technique to take a business decision [29]. The AHP technique has been exercised to choose the vendor and supplier [30,31]. The AHP technique was proposed by Professor Thomas L. Saaty in 1980.

There are many MCDM techniques and maximum research regarding MCDM dealing with theoretical development. A researcher may collect data from a particular firm and develop a new MCDM method for self-research or a project. It does not mean that the firm is using the MCDM method to make business decisions. The application of AHP in the pharmaceutical supply chain industry is very limited compared to other industries. Industry practitioners might not be ready to use any complex methodology of a method due to time, money, or technical constraints, especially in the developing world. Using heavy scientific language and methodology of a method or research may poor its application in industry. Any industrial firm is not using any MCDM method to select its supplier in Bangladesh. The success of the development of a method depends on its usefulness which relies on simplicity and user-friendliness. By considering this thought, this research has been conducted to show why and how an industrial firm can benefit in making business decisions from the AHP method using industry-friendly language and analysis patterns. Supplier selection, management, and purchasing policy are important facts in supply chain management. Previous studies have emphasized supplier selection by AHP, but this study has emphasized supplier selection with supplier management and appropriate purchasing policy by the AHP method. Further, explaining steps 1 to 5 in the methodology section, most of the previous studies have gone to the result and discussion section which might create difficulties in understanding the whole process for practitioners. This study has explained steps 1 to 8 in the methodology section in industry-friendly language and analysis patterns so that more business leaders may benefit from the APH method to make business decisions. Required data for this study have been collected from ACI Pharma. MS Excel has been used for data analysis.

First, the study selects the 5 attributes of the supplier selection problem based on the previous literature and 2-h-long FGD with the 8 management personnel of the company. The FGD participants were the head of supply chain management, director of marketing operations, manager of supply chain management, manager of procurement, marketing manager, a senior executive of logistics and planning, a senior executive of quality control, and a senior executive of quotation raising department of the company.

The study selects the following 5 attributes or criteria for the supplier selection problem.

Cost – the cost of printing materials (showcards, literature, and pad)
Quality – the quality of materials (attractiveness and durability of text, color, thickness)
Delivery-meeting with the delivery time mentioned in the quotation

Flexibility-desktop design department provides the text with the supplier, but sometimes the company needs to change the text and color. Also, the company has to change the delivery schedule sometimes. Does the supplier flexible to do the required change?
Communication-communication skills of suppliers in terms of presentation, e-mail, face-to-face, and over phone.

Among the above 5 supplier selection criteria, the cost is quantitative in nature measured in terms of local currency, TAKA, but the

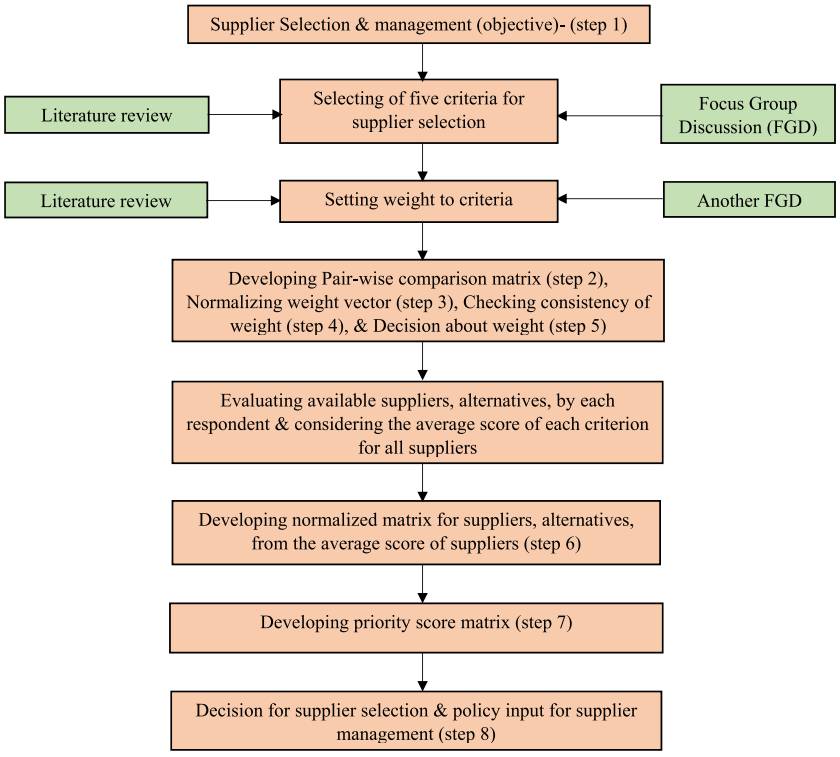

Fig. 1. Hierarchy of the methodology of the study.

other 4 criteria are qualitative in nature measured in terms of a 5-point Likert Scale. Fig. 1 contains the hierarchy of methodology of the study.

By using selected criteria, the study develops a pair-wise comparison matrix and weight vector and then measures the consistency ratio to check the acceptability and consistency of the weight. Further, it builds the matrix for the alternatives. Finally, the study finds the priority score matrix and takes the decision. Following are the steps of the process.

Step 1. Setting study objective and criteria.

To develop the required model, first, the DM should set the objective. Then, DM should set the attribute or criteria with the help of previous literature and FGD to develop the pair-wise comparison matrix.

Step 2. Developing the pair-wise comparison matrix.

To find out the consistent and acceptable weights of the attributes, researchers should develop a pair-wise comparison matrix to transfer verbal communication into mathematics using a discrete 9 points scale provided by Thomas L. Saaty, father of AHP, in 1980. The $n \times n$ pair-wise comparison matrix might be as follows-

$$A = (a_{ij}) = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix}$$

A is a $n \times n$ square matrix where the diagonal elements are the self-comparison of the attributes, so for diagonal elements $a_{ij} = 1$, where $i = j;$ *and* $i,j = 1,2,\ldots,n$.

On the other hand, the off-diagonal corresponding elements are reciprocal e.g., $a_{ij} = \frac{1}{a_{ji}}$, where $a_{ij} > 0, i \neq j$; and $i,j = 1,2,\ldots,n$.

Step 3. Calculating the weight vector.

It is one of the important steps of the AHP technique. The weight vector, the normalized eigenvector of the matrix, represents the weight of the criteria of the designed matrix in step 2. The geometric mean method along with the normalization technique is used to find out the normalized weight vector of the criteria. The sum of the normalized weight vector must be equal to 1.

Let, w_i , column vector, denote the importance degree or weight for the i th attribute or criteria, then, the w_i defined as follows [32].

$$w_i = \frac{\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}}{\sum_{i=1}^{n}\left(\prod_{j=1}^{n} a_{ij}\right)^{1/n}};\ i,j = 1,2,3,\ldots,n;\ \text{and } W = \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix}$$

Step 4. Testing the consistency of the weights.

Consistency checking is an important step of the total process because it tells how consistent and acceptable the weights one finds are. Let C is the n dimensional column vector that represents the weighted values for the importance degrees of the criteria, then C is defined as follows [33].

$$C = (c_i) = A.W^T_{n\times 1} = \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_n \end{pmatrix}, i = 1,2,3,\ldots,n$$

$A.W^T$ is defined as follows-

$$A.W^T = \begin{pmatrix} a_{11} & a_{12} & \cdots & a_{1n} \\ a_{21} & a_{22} & \cdots & a_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ a_{n1} & a_{n2} & \cdots & a_{nn} \end{pmatrix} * (w_1, w_2, \ldots, w_n)^T$$

Now, the Consistency Value (CV) of the attributes might be defined by the following vector

$$CV = (cv_i)_{n\times 1} = \frac{c_i}{w_i}, i = 1,2,3,\ldots,n$$

As different measurement scales have been used for different attributes, so Saaty suggested using the maximal eigenvalue, λ_{max}, to avoid inconsistency in the evaluation process. The λ_{max} is defined as follows-

$$\lambda_{max} = \frac{\sum_{i=1}^{n} cv_i}{n}, i = 1,2,3,\ldots,n$$

The Consistency Index (CI) is defined as follows-

$$CI = \frac{\lambda_{max} - n}{n-1}$$

To check the consistency of the weights, finally, the Consistency Ratio (CR) is calculated as follows-

$$CR = \frac{CI}{RI}$$

The RI, Random Index, is a given value in the calculation process.

Step 5. Decision about weights of the attributes.

For consistent and acceptable weights, the CR value must be less than 0.1. If the value of CR is less than 0.1, the weight is consistent, and the calculation process is acceptable. On the other hand, if the CR value is greater than 0.1 then the weight is inconsistent, so the calculation process must be repeated by redefining the value of the attributes.

Step 6. Developing and normalizing another matrix for alternatives.

In this research, the available alternatives mean the available suppliers, so the matrix might be as follows-

$$S = \left(s_{ij}\right)_{m\times n} = \begin{pmatrix} s_{11} & s_{12} & \cdots & s_{1n} \\ s_{21} & s_{22} & \cdots & s_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ s_{m1} & s_{m2} & \cdots & s_{mn} \end{pmatrix}$$

$i = 1, 2, 3, \ldots, m$; the number of alternatives, suppliers in this research

$j = 1, 2, 3, \ldots, n$; the number of attributes or criteria

$s_{ij} = i^{\text{th}}$ alternative value for the j^{th} attribute

There are different types of attributes. For some attributes, the quality, DM wants the maximum value. On the other hand, for some attributes, the cost, DM wants the minimum value. To address these issues, the researcher should normalize the attributes, so attributes can be measured in a unique numerical form. The normalization is done in such a way that each element of each column of the matrix S must lie between 0 and 1. The normalization technique is different based on the category of the attributes.

For the maximum value expecting attribute, quality in this research, at first, find the maximum value of a specific column and then divide each element of that column by the maximum value. For example, let, s_{21} is the maximum value of the first column of the matrix S then the normalization process is-

$$\widehat{s}_{i1} = \frac{s_{i1}}{s_{21}}; i = 1, 2, 3, \ldots, m$$

Where, $\widehat{s}_{i1}$ is the normalized value of s_{i1}, the first column elements of the matrix S.

For the minimum value expecting criterion, the cost in this research, at first, finds the minimum value of a specific column and then divides the minimum value by each element of that column. For example, let, s_{22} is the minimum value of the second column of the matrix S then the normalization process is-

$$\widehat{s}_{i2} = \frac{s_{22}}{s_{i2}}; i = 1, 2, 3, \ldots, m$$

Where, $\widehat{s}_{i2}$ is the normalized value of s_{i2}, the second column elements of the matrix S.

After normalization, let the normalized matrix, $\widehat{S}$, is as follows-

$$\widehat{S} = \left(\widehat{s}_{ij}\right) = \begin{pmatrix} \widehat{s}_{11} & \widehat{s}_{12} & \cdots & \widehat{s}_{1n} \\ \widehat{s}_{21} & \widehat{s}_{22} & \cdots & \widehat{s}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widehat{s}_{m1} & \widehat{s}_{m2} & \cdots & \widehat{s}_{mn} \end{pmatrix}$$

$\widehat{s}_{ij} = i^{\text{th}}$ normalized alternative value for the j^{th} attribute.

Step 7. Finding the priority score matrix.

The researcher finds the priority score for each alternative by the multiplication of the normalized alternative matrix, $\widehat{S}$, and the criteria weight vector, W.

Let, P is the required priority score matrix defined as follows-

$$P = \widehat{S} \ * \ W = \left(\widehat{s}_{ij}\right)_{m\times n} * \left(w_i\right)_{n\times 1} = \begin{pmatrix} \widehat{s}_{11} & \widehat{s}_{12} & \cdots & \widehat{s}_{1n} \\ \widehat{s}_{21} & \widehat{s}_{22} & \cdots & \widehat{s}_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ \widehat{s}_{m1} & \widehat{s}_{m2} & \cdots & \widehat{s}_{mn} \end{pmatrix} * \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix}$$

$$P = \left(p_i\right)_{m\times 1} = \begin{pmatrix} p_1 \\ p_2 \\ \vdots \\ p_m \end{pmatrix}; \ i = 1, 2, 3, \ldots, m \ ; \text{ number of alternatives}$$

The priority score matrix, P, is a $m \times 1$ dimensional column matrix that holds the overall score of each alternative.

Step 8. Decision making.

Based on the overall score in the priority matrix, P, one alternative, supplier, is prioritized over another. The highest overall score gainer is the best alternative among all available alternatives, the second highest score gainer is the second-best alternative, the third

highest score gainer is the third-best alternative, and so on. After supplier selection, researchers should input the policy for purchasing methods and supplier management techniques.

3. Results and discussion

ACI Pharma spends $ 12 to 15 million per year on brand promotion. Its promotional cost is distributed as 30% on printing materials, 19% on physician samples for drug testing, 17% on special activities like FGD with customers, and 34% on gifts like clothing. The company has a high purchase volume and cost for printing materials. Further, these materials carry various scientific information about drugs and the company image, so materials bear a high impact value for the company. On the other hand, there are so many local suppliers to supply the printing materials, so it has a low supply risk. The printing materials are the leverage items for ACI Pharma. A company has higher strategic importance with lower supply risk for leverage items. The leverage items have lower supply risks involving a higher impact on business [34]. Before developing the pair-wise comparison matrix, the study finds the required degree of importance of the attributes at hand based on the fundamental scaling system developed by Thomas L. Saaty in 1980. Table 1 contains Saaty's scaling system.

The hierarchy of supplier selection with 5 criteria or attributes has been presented in Appendix 1. Based on the selected 5 attributes and scaling system, the study finds a pair-wise comparison value in Table 2 to develop the required pair-wise comparison matrix.

The tabulated values are the degree of importance of one attribute over another. This degree of importance of the attributes has been selected from the literature review and another FGD with the 5 management personnel of ACI Pharma. The duration of the FGD was 2 h long, and the participants were the head of supply chain management, director of marketing operations, manager of supply chain management, manager of procurement, and manager of marketing. The study develops the expected pair-wise comparison matrix, A, based on the tabulated value of the attributes.

$$A=\begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} & a_{15} \\ a_{21} & a_{22} & a_{23} & a_{24} & a_{25} \\ a_{31} & a_{32} & a_{33} & a_{34} & a_{35} \\ a_{41} & a_{42} & a_{43} & a_{44} & a_{45} \\ a_{51} & a_{52} & a_{53} & a_{54} & a_{55} \end{pmatrix}=\begin{pmatrix} 1 & 0.143 & 0.200 & 0.333 & 0.500 \\ 7 & 1 & 3 & 3 & 2 \\ 5 & 0.333 & 1 & 4 & 4 \\ 3 & 0.333 & 0.250 & 1 & 2 \\ 2 & 0.500 & 0.250 & 0.500 & 1 \end{pmatrix}$$

The diagonal elements of the matrix A indicate the equal importance of the attributes, so the value of all diagonal elements must be equal to 1 which means the comparison of cost to cost is 1, quality to quality is 1, delivery to delivery is 1, and so on. The value of the off-diagonal elements must be less than or greater than 1. In this research, quality and cost comparison is $a_{21}=7$, the quality is very strongly important than the cost, so cost and quality comparison is $a_{12}={}^{1}/_{a_{21}}={}^{1}/_{7}=0.143$.

Delivery and cost comparison value is $a_{31}=5$, the delivery is strongly important than the cost, so cost and delivery comparison is $a_{13}={}^{1}/_{a_{31}}={}^{1}/_{5}=0.200$.

The normalized weight vector, W, of the pair-wise comparison matrix, A, is as follows-

$$W=\begin{pmatrix} w_{a_1} \\ w_{a_2} \\ w_{a_3} \\ w_{a_4} \\ w_{a_5} \end{pmatrix}=\begin{pmatrix} 0.053 \\ 0.409 \\ 0.300 \\ 0.135 \\ 0.103 \end{pmatrix}$$

In this research, the highest weight is 0.409 for the quality attribute, the second highest weight is 0.300 for the delivery attribute, the third highest weight is 0.135 for the flexibility attribute, the fourth highest weight is 0.103 for the communication attribute, and the lowest weight is 0.053 for the cost attribute. The sum of the normalized weight vector is 1, $0.053+0.409+0.300+0.135+0.103$, which indicates the weight calculation is correct. How consistent the weight is? This is the big question in the process.

To check the consistency of the calculated weight, the study calculates the 5-dimensional column vector, C, as follows-

Table 1
Fundamental scaling system of attributes.

Degree of Importance	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2, 4, 6, 8	Intermediate Importance between two adjacent judgments

Table 2
Pair-wise comparison values of the 5 selected attributes.

Attributes	A_1 (cost)	A_2 (quality)	A_3 (delivery)	A_4 (flexibility)	A_5 (communication)
A_1 (cost)	1	0.143	0.200	0.333	0.500
A_2 (quality)	7	1	3	3	2
A_3 (delivery)	5	0.333	1	4	4
A_4 (flexibility)	3	0.333	0.250	1	2
A_5 (communication)	2	0.500	0.250	0.500	1

$$C = A * W = \begin{pmatrix} 1 & 0.143 & 0.200 & 0.333 & 0.500 \\ 7 & 1 & 3 & 3 & 2 \\ 5 & 0.333 & 1 & 4 & 4 \\ 3 & 0.333 & 0.250 & 1 & 2 \\ 2 & 0.500 & 0.250 & 0.500 & 1 \end{pmatrix} * \begin{pmatrix} 0.053 \\ 0.409 \\ 0.300 \\ 0.135 \\ 0.103 \end{pmatrix} = \begin{pmatrix} 0.268 \\ 2.293 \\ 1.654 \\ 0.712 \\ 0.556 \end{pmatrix}$$

Now, the Consistency Value (CV) of the criteria is as follows-

$$CV = \frac{C_i}{W_i} = \begin{pmatrix} 5.025 \\ 5.607 \\ 5.519 \\ 5.260 \\ 5.425 \end{pmatrix}$$

To avoid inconsistency in the evaluation process, the maximal eigenvalue, λ_{max}, is as follows-

$\lambda_{max} = \frac{\sum_{i=1}^{5} cv_i}{5}$, i is the number of criteria or attributes.

$$= \frac{5.025 + 5.607 + 5.519 + 5.260 + 5.425}{5}$$

$= 5.367.$

The Consistency Index, CI, of the study is as follows-

$CI = \frac{\lambda_{max} - n}{n-1}$; n = 5, number of criteria, in this research

$$= \frac{5.367 - 5}{5 - 1}$$

$= 0.0918.$

Finally, the Consistency Ratio, CR, of this study is as follows-

$CR = \frac{CI}{RI}$; the RI is the random index that is a given value.

The RI value for 1 to 10 criteria is given in Table 3 [35].

This research has 5 attributes, so the RI value for this study is 1.12.

$$CR = \frac{0.0918}{1.12} = 0.0819 < 0.1$$

As the CR value is less than 0.1, so the weight of this study is consistent and acceptable.

In the last 6 months from July to December of 2022, ACI Pharma purchased the printing materials from 25 suppliers, but the top 10 suppliers supply 90.8% of the materials, so the study initially considers 10 suppliers as available alternatives to select the best supplier. Table 4 contains the top 10 suppliers of ACI Pharma.

These 10 suppliers have been independently and identically evaluated with a structured questionnaire by the 15 senior executives of ACI Pharma associated with raising quotations, communicating with suppliers, passing the design to suppliers, checking machine proof, and ensuring the delivery of the materials. The questionnaire contains the 4 qualitative attributes, quality, delivery, flexibility, and communication, evaluated in the 5-point Likert Scaling system. For all qualitative attributes, the maximum value indicates the maximum satisfaction. For the very good, good, average, poor, and very poor option in the scaling system, the points were 5, 4, 3, 2, and 1, respectively, in this study. After evaluation, the study calculates the average score of each supplier for each attribute.

Another attribute is the cost, for which the minimum value indicates the maximum satisfaction. The company has different types of printing materials, but showcard is 62.3%, literature is 19.5%, and pad is 8.2% among all types of materials. Further, every supplier supplies these 3 materials. For the cost criterion, the study has considered the average cost of 1000 showcards, 1000 literature, and 1000 pads each supplier has supplied to the company. For example, the cost of S_1 is the sum of the average cost of 1000 showcards,

Table 3
The Random Index value for the 1 to 10 attributes.

n	1	2	3	4	5	6	7	8	9	10
Random Index (RI)	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49

Table 4
Top 10 printing materials suppliers of ACI Pharma.

Notation	Supplier Name	Supplied Material Value (%)
S_1	Lutfur Enterprise	17.1
S_2	Spark Printers	16.8
S_3	Quality Printing & Packaging	11.2
S_4	Rupa Printing & Packaging	9.0
S_5	Marvelous Printers Ltd.	8.3
S_6	Abir Enterprise	7.4
S_7	Graph Tech Printing and Packaging	6.2
S_8	Siddique Printers	6.1
S_9	Intimacy Printers	5.1
S_{10}	Dot Line Printers	3.6
	Total of top 10 Supplier	90.8

1000 literature, and 1000 pads.

Cost of S_1 = average 1000 showcard cost + average 1000 literature cost + average 1000 pad cost

$= 3722 + 9649 + 39{,}051 = 52{,}422$

Cost of S_2 = average 1000 showcard cost + average 1000 literature cost + average 1000 pad cost

$= 4067 + 8428 + 32{,}178 = 44{,}673$

The study develops Table 5 to present the attribute-wise average score of suppliers.

Now, the study develops the matrix, S, for the available alternatives, suppliers, based on the attribute-wise average score of suppliers presented in Table-5.

$$S = \begin{pmatrix} 52,422 & 3.800 & 3.600 & 3.400 & 3.533 \\ 44,673 & 3.867 & 3.867 & 3.733 & 4.067 \\ 25,460 & 3.000 & 3.000 & 3.133 & 3.267 \\ 43,811 & 3.133 & 3.000 & 3.000 & 3.000 \\ 43,789 & 3.733 & 3.733 & 3.400 & 3.800 \\ 17,926 & 3.467 & 3.267 & 3.067 & 2.933 \\ 36,927 & 3.533 & 3.333 & 3.333 & 3.467 \\ 24,702 & 2.733 & 2.800 & 2.600 & 2.667 \\ 37,749 & 3.533 & 3.000 & 3.000 & 3.333 \\ 22,975 & 3.400 & 3.000 & 3.000 & 3.333 \end{pmatrix}$$

The matrix, S, is normalized in such a way that each element of the matrix must lie between 0 and 1. After normalization, the study finds the normalized matrix, $\widehat{S}$, as follows-

Table 5
The attribute-wise average score of suppliers.

Supplier	A_1 (cost)	A_2 (quality)	A_3 (delivery)	A_4 (flexibility)	A_5 (communication)
S_1	52,422	3.800	3.600	3.400	3.533
S_2	44,673	3.867	3.867	3.733	4.067
S_3	25,460	3.000	3.000	3.133	3.267
S_4	43,811	3.133	3.000	3.000	3.000
S_5	43,789	3.733	3.733	3.400	3.800
S_6	17,926	3.467	3.267	3.067	2.933
S_7	36,927	3.533	3.333	3.333	3.467
S_8	24,702	2.733	2.800	2.600	2.667
S_9	37,749	3.533	3.000	3.000	3.333
S_{10}	22,975	3.400	3.000	3.000	3.333

$$\widehat{S} = \begin{pmatrix} 0.342 & 0.983 & 0.931 & 0.911 & 0.869 \\ 0.401 & 1.000 & 1.000 & 1.000 & 1.000 \\ 0.704 & 0.776 & 0.776 & 0.839 & 0.803 \\ 0.409 & 0.810 & 0.776 & 0.804 & 0.738 \\ 0.409 & 0.966 & 0.966 & 0.911 & 0.934 \\ 1.000 & 0.897 & 0.845 & 0.821 & 0.721 \\ 0.485 & 0.914 & 0.862 & 0.893 & 0.852 \\ 0.726 & 0.707 & 0.724 & 0.696 & 0.656 \\ 0.475 & 0.914 & 0.776 & 0.804 & 0.820 \\ 0.780 & 0.879 & 0.776 & 0.804 & 0.820 \end{pmatrix}$$

Finally, the study finds the priority score matrix, P, is as follows-

$$P = \widehat{S} * W = \begin{pmatrix} 0.342 & 0.983 & 0.931 & 0.911 & 0.869 \\ 0.401 & 1.000 & 1.000 & 1.000 & 1.000 \\ 0.704 & 0.776 & 0.776 & 0.839 & 0.803 \\ 0.409 & 0.810 & 0.776 & 0.804 & 0.738 \\ 0.409 & 0.966 & 0.966 & 0.911 & 0.934 \\ 1.000 & 0.897 & 0.845 & 0.821 & 0.721 \\ 0.485 & 0.914 & 0.862 & 0.893 & 0.852 \\ 0.726 & 0.707 & 0.724 & 0.696 & 0.656 \\ 0.475 & 0.914 & 0.776 & 0.804 & 0.820 \\ 0.780 & 0.879 & 0.776 & 0.804 & 0.820 \end{pmatrix} * \begin{pmatrix} 0.053 \\ 0.409 \\ 0.300 \\ 0.135 \\ 0.103 \end{pmatrix}$$

$$= \begin{pmatrix} 0.912 \\ 0.968 \\ 0.783 \\ 0.770 \\ 0.925 \\ 0.858 \\ 0.866 \\ 0.706 \\ 0.824 \\ 0.827 \end{pmatrix}$$

The S_2 supplier, Spark Printers, is the best supplier to supply the printing materials to ACI Pharma as it obtains the highest score, 0.968, in the priority score matrix. The S_5 supplier, Marvelous Printers Limited, is the second-best as it obtains the second-highest score, 0.925, in the matrix; the S_1 supplier, Lutfur Enterprise, is the third-best as it makes the third-highest score, 0.912, in the matrix; the S_7 supplier, Graph Tech Printing and Packaging, is the fourth-best since it makes the fourth-highest score, 0.866, in the matrix; and so on. The overall priority score of 10 suppliers has been presented in a bar chart in Appendix 2.

Supplier selection is an important part of the supply chain, but purchasing technique and supplier management policy are the other vital issues in supply chain management. Supplier selection, contracting, purchasing, management techniques, payment methods, and similar things have become critical success factors for a modern firm because a firm purchases at least 50% of its turnover [36]. The printing materials are the leverage items for ACI Pharma. The suitable purchasing technique for the leverage items may be dealing with a short-term contract based on negotiation with suppliers. An organization may gain maximum satisfaction by signing a short-term contract with the suppliers for leverage items [37]. ACI Pharma should negotiate with the top 3 suppliers to sign a short-term, 1-2-year, contract to purchase the required printing materials to maintain smooth brand promotional activities. Today a supplier is good, but tomorrow that supplier might be poor. Supplier selection and purchasing techniques are important, but management is very important. To manage the required supplier, the company should monitor and evaluate the performance of the supplier after a specific period, quarterly or bi-annually, by using the AHP during the contract period in the same process. If the contracted supplier violates the agreement, a penalty should be imposed. After ending a successful contract period, ACI Pharma should re-evaluate all available suppliers of printing materials by using the AHP in the same process to enjoy better bargaining power, purchasing method, and management technique.

In the present world, industry 4.0 and sustainability are effective buzzwords creating new issues in the industry. The fourth industrial revolution generates many challenges in different industries and enterprises [38]. The concept of green supply chain management is popular among academicians, and the publication and research in this sector are still growing [39]. Sustainable supplier selection has become a critical concern for companies [40]. In this study, all supplier selection criteria have come from the economic dimension avoiding social and environmental dimensions of sustainability. Researchers, scientists, and academicians are raising voices for sustainability in the supply chain, production, and other sectors of industries worldwide. On the other hand, decision-makers, business leaders, and industry practitioners in developing countries like Bangladesh are raising voices for the economic benefits of avoiding social and environmental issues. The collaboration and cooperation between the developed and developing world, academicians and practitioners, and theoretical development and practical applications of various methods should be improved based on simplicity to overcome this issue.

4. Conclusion

Most of the research on MCDM has dealt with theoretical development rather than model selection and practical application in industry. The application of AHP in the pharmaceutical supply chain industry is very limited. Moreover, industry practitioners in developing countries like Bangladesh may not be interested to use a complex form of method taking business decisions due to time, money, or technical constraints. The study tries to show why, when, and how a firm can use AHP to make wise business decisions based on industry-friendly language and analysis patterns in the pharmaceutical supply chain industry. ACI Pharma used to select its suppliers of printing materials based on subjective judgment and faced problems regarding the quality and delivery of materials that hampered brand promotional activities, so the company lost its market share and profit. The company arranged several meetings with the supply chain, marketing, and sales leader to overcome this problem. As an employee of ACI Pharma, the author proposed the AHP method to solve the problem. The company selects the 5 criteria, cost, quality, delivery, flexibility, and communication, for the supplier selection problem. Spark Printers, Marvelous Printers Limited, and Lutfur Enterprise are the best suppliers among the 10 available suppliers of ACI Pharma. The company should negotiate with these 3 suppliers and sign a short-term contract to purchase the required printing materials. To manage the supplier, the company should replicate the process, quarterly or bi-annually, using the AHP method during the contract period. First time in Bangladesh, ACI Pharma is using the AHP method to select and manage its supplier. ACI is a leading conglomerate in Bangladesh, so other corporates in Bangladesh may use the AHP method to select and manage their suppliers. Other industrial firms facing similar business problems may be beneficiaries of this study.

Various MCDM techniques are present, such as AHP, ANP, QFD, and TOPSIS, so a model selection should be based on methodological justification. The study depends on the AHP without any justification means why AHP should be used to address the supplier selection problem in the pharmaceutical supply chain industry. To overcome this limitation, further studies might be conducted to identify which MCDM method fits best for the pharmaceutical supply chain industry, as every industry has different challenges and solutions. Even without any methodological justification, one may apply other MCDM techniques to replicate the study to show the consistency of the result. The study emphasizes industry-friendly language and analysis patterns instead of scientific ones is another drawback. Most of the research regarding MCDM has focused on theoretical development, but one of the success factors of theoretical development relies on practical application depends on simplicity and user-friendliness. Considering this thought, the study has emphasized industry-friendly language and analysis patterns to encourage more industry practitioners to make wise decisions using AHP in complex situations combining qualitative and quantitative variables simultaneously.

The economy, society, and environment are the 3 pillars of the sustainable supplier selection process. The study has considered only economic dimensions omitting social and environmental dimensions. The academicians are raising voices for green supply chain management worldwide, but industry leaders are making business decisions based on traditional supply chain management in Bangladesh. An additional hint of the study is a supplier selection process in developing countries like Bangladesh avoids social and environmental dimensions of sustainability, but further study is required regarding the this. The collaboration and cooperation between academicians and practitioners should be improved based on simplicity to overcome the issue.

Author contribution statement

Mehedi Hasan Manik: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare that they have no known competing interests.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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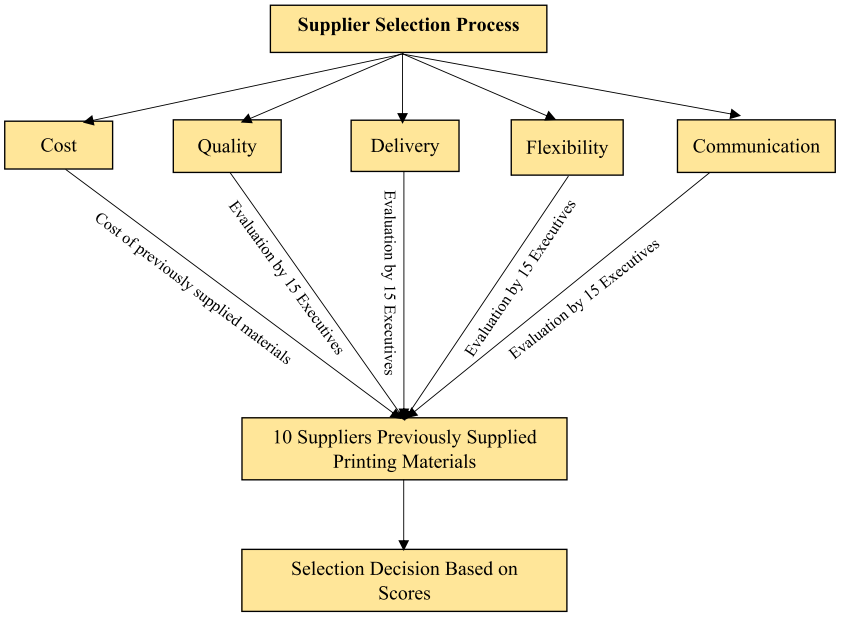
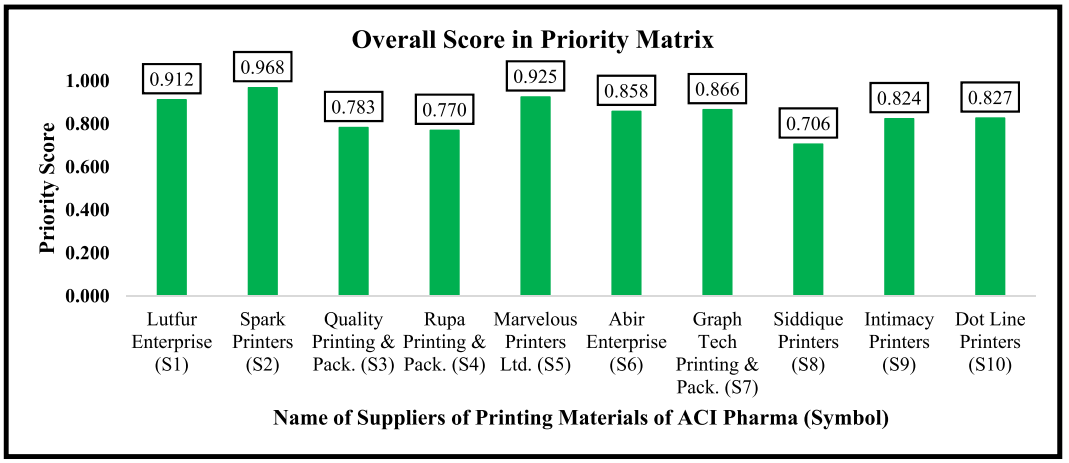
Appendix

Appendix 1: The hierarchy of supplier selection with 5 criteria.



Appendix 2: The overall priority score of 10 suppliers of ACI Pharma.



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