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Integration of AHP and TOPSIS for Evaluation and Selection of Artificial Intelligence Vendors

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Abstract— ***Artificial Intelligence (AI) refers to technologies that try to mimic various attributes of human intelligence, such as learning, understanding, problem-solving, and judgment. Therefore, AI can help businesses improve customers' satisfaction and firms' productivity, make smart decisions, etc. To optimize the efficient implementation of AI, firms have to consider all resources and options available. In the development and implementation of an AI technology, the first question is whether firms should outsource it to an AI vendor, or insource it. Once a firm decides that it wants to outsource the execution of an AI project, the selection of the best vendor is critical. Vendors must be evaluated and selected against some conflicting factors that may not be equally important. In this study, we first discuss how to (1) make a wise insourcing-outsourcing decision, and (2) determine the important criteria for vendors' evaluation and selection. We then integrate the Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) that helps facilitate the accurate evaluation of the potential vendors. We also use numerical analysis to illustrate the accuracy and effectiveness of the proposed model.***

Index Terms—Artificial intelligence; Supplier selection problem; MCDM; AHP; TOPSIS.

I. INTRODUCTION

Technology is a force of change that successful businesses must keep front of mind. Artificial Intelligence (AI) is no exception, and in fact, is maybe the biggest technological advancement that will change the world in the coming years. A survey of industry scholars and practitioners defined AI as a software that exhibits traits that we find in humans [1]. There is no doubt that AI benefits firms in various ways. Compared to human beings, AI machines can analyze large amounts of data within a few seconds to make a quick and accurate decision. Also, AI machines can work without any break that, for example, enable firms to automate communications through emails, online chats, etc. All of these capabilities help businesses improve customer satisfaction, productivity and profitability. AI has the ability to increase firms' productivity by 40% or more, and profitability by an average of 38% [2]. AI will soon be at the forefront of the business world and play a pivotal role in the growth of firms around the globe. Therefore, understanding how to best make use of the technologies will become increasingly important. Despite the benefits of AI for companies, only 9% of them in the U.S. have actually begun using AI [3], and just 10% of those have seen significant financial returns [4].

One reason that firms are not getting the most out of the AI technologies can be rooted in the firms' readiness and ability to implement and adopt an AI technology. Alsheibani et al. [5], a research-in-progress publication, draws on the TOE (technological, organizational, environmental) framework for AI adoption at the firm level. Pumplun et al. [6] explored organizational readiness factors to adopt AI in organizations through a qualitative interview approach. Paul [7] built on Alsheibani's work regarding the TOE framework and conducted an exploratory case study of the internal and external factors influencing an organization's ability to adopt AI. Uren [8] investigated critical success factors of AI projects by analyzing firms based on the Technology Readiness Level scale. Jöhnk et al. [9] presented five categories of AI readiness factors and their illustrative actionable indicators by an in-depth interview study with 25 AI experts. Denicolai et al. [10] addressed the organizational readiness of AI within small and medium-sized enterprises.

Now, a natural next question is if companies are ready to implement and adopt an AI technology, should it be insourced, or outsourced to an AI vendor? If outsourcing is the best choice for a company, the second question should be how a firm can evaluate the vendors and select the best one? To the best of our knowledge, none of the studies in the relevant literature, has addressed these two questions. In this study, we first discuss how to (1) make a wise insourcing-outsourcing decision, and (2) determine the important criteria for vendors' evaluation and selection. We then developed an integration of AHP and TOPSIS to evaluate and rank the AI vendors.

Implementation of the AHP and TOPSIS methodologies has been studied within the context of the oil, locomotives, logistics, steel, sustainability, manufacturing, and food supply industries. Specifically, Amiri [11] incorporated the AHP and TOPSIS techniques to help decision-makers (DMs) select the best National Iranian Oil Company by weighing six separate factors. Kumar et al. [12] proposed two example solutions analyzing the supplier selection decision for the Indian Locomotive industry based on some criteria. Bianchini [13] applied AHP and TOPSIS to research the decision-making process when deciding on a third-party logistics provider. Azimifard et al. [14] explored the application of AHP and TOPSIS to determine the top sustainable supplier for Iran's steel industry. Mohammed et al. [15] considered an integration of AHP and TOPSIS to optimize the environmentally friendly selection of suppliers. Kumar et al. [16] utilized AHP and TOPSIS to determine the most important characteristics for the successful implementation of agile manufacturing. Leung [17] conducted a case study researching the usefulness of AHP and TOPSIS to enhance produce selection for food retailers. Based on the above examples, we believe AHP and TOPSIS integration can help DMs when choosing the best AI vendor.

We organize the remainder of the paper as follows. In Section 2, we discussed (1) how companies can make an insourcing-outsourcing decision, and (2) what factors can be used to evaluate the AI vendors. Section 3 develops the integration of AHP and TOPSIS for the vendors' evaluation and selection. Section 4 uses numerical analysis to demonstrate the effectiveness of the proposed solution. Section 5 draws some conclusions and suggests future research directions.

II. MAKING AND INSOURCING-OUTSOURCING DECISION

A. Outsourcing vs Insourcing

A question of this research considers what companies must do if they want to use an AI technology: do they have to develop it in-house, or outsource it to another firm? Figure 1, depicting the insourcing-outsourcing decision matrix, can provide direction for companies to make this decision.

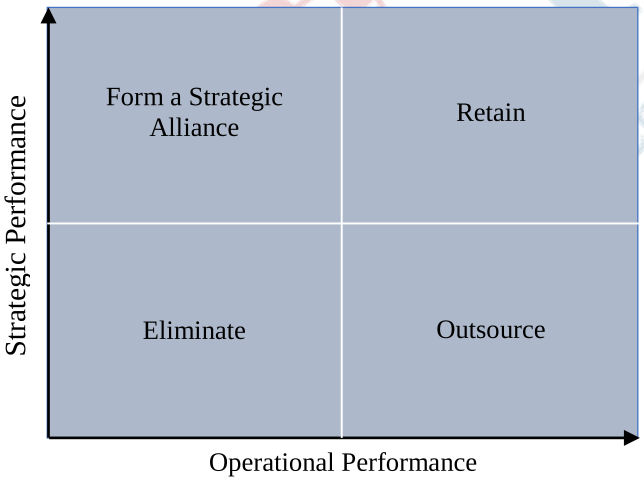

Figure 1. The Outsourcing Decision Matrix [18].

The insourcing-outsourcing decision matrix has four options as shown in Figure 1: Eliminate, Outsource, Retain (or build in-house), and Form a Strategic Alliance. These four factors are judged based on the comparison between contribution to operational performance and strategic importance listed on the X- and Y-axis, respectively. For this research, outsourcing and building in-house are the relevant factors under consideration, because our question assumes the make or buy decision. The strategic importance of a project can be thought of as the competitive advantage of a given task. In other words, does the task in question give a business a competitive advantage? In contrast, the contribution to operational performance can be thought of as the operational importance of the task. How much does the task contribute to the efficiency of an organization? If a task has high strategic importance and has a significant contribution to operational performance, then it makes sense to build the solution in-house.

Consider the case of Zillow, a real estate company founded in 2004, packaged automated valuation (Machine learning) methods for retail on a large scale as their core innovation [19]. Zillow's AI initiatives make a high contribution to its both operational and strategic performances because its business is based on the optimization of the data and insight. As a result, they have established their own AI and Analytics team to further advance their business objectives using AI. They not only care about successfully implementing AI projects, but owning the rights to the data, knowledge, and technology to separate themselves from their competitors. On the other hand, if a task has low strategic importance but high contribution to operational performance, then the project should probably be outsourced. For example, Denny's realized that they needed to invest in a technology solution that would strengthen and improve their visibility across online search results. Denny's used the Yext technology platform to resolve the issue instead of creating proprietary technology [20, 21]. Yext is a technology company operating in the area of online brand management. As discussed, Taco Bell and Denny's did not require proprietary AI, but rather utilized applications already built by Yext. In their case, the implementation of AI significantly contributed to their operational performance, but still was not of critical strategic importance. By choosing to outsource, they saved time and money by not having to create a new department. If a firm is confident the use of AI will contribute to its operational performance, but not its long-term strategy, then it is time to choose an AI vendor.

In order to determine whether it makes more sense to build in-house, or outsource to a consultant or a vendor, we also discuss the following determinative factors based on research conducted by Porter [22].

Cost and Resources

1. What resources and technology are required to do the job? Does the organization already possess them?
2. What data is required and is the company equipped to collect and manage this itself?
3. How much would it cost to outsource compared to developing the solution in-house?

For the first two questions, if the company does not already possess the necessary staff and technology for data collection, etc., then naturally, the next question is whether outsourcing will be cheaper than acquiring all these resources. If you find

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outsourcing would be a good deal less expensive, then that probably makes sense. However, the expected quality and efficiency of the project should also be considered.

Quality and efficiency

4. Would outsourcing or building a team in-house produce a higher quality product?
5. How much does the quality of the solution matter?
6. How long will it take to outsource compared to doing in-house? Is the project time-sensitive?
7. Would outsourcing increase the organization's operational efficiency?
8. Can the company trust a third party to develop this part of the business?

For the above five questions, one really has to consider what the overall goal with the project is, and how the task fits into the organization's pre-existing operations over time. Is the quality paramount to the project's success? Then building in-house may make sense due to contractors not putting the same level of care and commitment as its own organization. Must the project be executed before a specific date or is there a looser timeline for completion? If you determine the task has a project deadline and could be performed faster by a consultant, then it probably makes sense to outsource. Of course, you also have to consider the competitive advantage you seek to gain from the project and the strategic importance down the road.

Competitive advantage and strategic importance

9. What is the strategic importance of this project?
10. Will this project be a part of the company's competitive advantage in the future?

These final two questions are the most important to answer. If a company determines that the project is of high strategic importance and will play a critical role in its competitive advantage, it may make sense to make the long-term investment to build the solution in-house; the intellectual property will eventually become a crucial asset. Overall, the main factors for consideration are the project's timeline, cost, and strategic importance. If the task is time-sensitive and cheaper to hire outside talent, then outsourcing may be wise. However, the strategic importance of the project should not be forgotten and may be the deciding factor depending on the significance of the intellectual property rights. If a competitive advantage can be developed through the utilization of data and AI, then it can oftentimes make sense to develop a team to work within the organization. As discussed, Zillow, Taco Bell, and Denny's are the examples.

B. Factors Used for Vendors' Evaluation and Selection

The next relevant question is if a firm decides to outsource an AI project to a vendor, what factors should be considered to evaluate the vendors and select the best one. The following question framework may help firms apply the important factors for vendors' evaluation and selection. The questions were developed based on the research of Porter [22]:

1. How complex will the AI solution be? (difficulty to deliver)
2. Do the vendors prioritize align with the project needed? (compatibility)
3. How many vendors offer the required service? (number of options available)
4. How knowledgeable are the vendors? Are they an expert in your domain/industry? (knowledge)
5. How long have they been in business? (longevity)
6. What is the quality of the vendors' product? (quality)
7. How reliable are the vendors? (reliability)
8. How is the vendors' reputation? (reputable)
9. Are the vendors available and how long will it take to do it? (timing)
10. Do the vendors maintain professional communication? (communication)
11. What is the cost? Is the cost hourly or by the project? (cost)

First, what is the use case, and what features and services are needed? The primary goal of this question is to determine what specific technology is needed. Second, do the vendors prioritize align with the project needed? A firm should know and trust that the vendor's interests are aligned with its organization to avoid conflict down the road. Third, how many vendors offer the required service? This will let the firm know to what extent AI has been implemented into their industry and whether the buyers or vendors hold the power for its specific project. Similarly, how knowledgeable are the vendors, and are they an expert in the firm's domain? The firm likely does not want to hire an outside team if they are not well versed in the inner workings of its industry. Industry knowledge is often very important, because companies typically do not want to pay a vendor while they come up the learning curve of a particular market. Ideally, the vendor is so experienced they can actually teach the company some things. Fifth, how long have the vendors been in business? It is important to know whether the vendor has been running a successful operation for a long time or just beginning the endeavor. Next, what is the quality of the vendors' product? The quality of a vendor should always be weighed against the price they are asking. Additionally, how reliable are the vendors? In other words, do they have a solid track record of meeting deadlines and delivering projects on time? A firm should also consider the reputation of the vendors. Is there any history of shady business dealings or questionable ethics regarding data protection? Can the vendors provide sufficient data security? Subsequently, are the vendors available and how long will it take them to complete the project? A firm should also examine the vendors' ability to communicate. Namely, has the vendor demonstrated a history of maintaining professional communication? Last but not least, what is the asking price of the vendors? Does the price seem reasonable based on the firm's appraisal of their business? As discussed here, the factors for vendors' evaluation and selection are summarized as: Compatibility (F_1), Knowledge (F_2), Longevity (F_3), Product Quality (F_4), Reliability (F_5), Reputation (F_6), Availability (F_7), Communication (F_8), and Cost (F_9).

III. INTEGRATION OF AHP AND TOPSIS

After identifying the factors to be considered for vendors' evaluation and selection, we propose a methodology consisting of two stages as follows. We first obtain the weights of each factor by using the AHP technique, and then input these weights to the TOPSIS method to evaluate and rank the vendors. Assume that there are *n* vendors, i = 1, 2, …, n, and m factors, $j = 1, 2, \ldots, m$. Some of the factors are benefit attributes, such as reputation, and some are cost attributes, such as cost and time.

A. Determine Weight of Factors by AHP

In this stage, we use the AHP technique to quantify managerial judgments of the relative importance or the weight of each of factors determined in the previous section. To do so, we use the following steps:

Step 1. List the goal and the factors.

The goal is to determine the factors' relative importance or weight. As discussed in the previous section, the factors are Compatibility (F_1), Knowledge (F_2), Longevity (F_3), Product Quality (F_4), Reliability (F_5), Reputation (F_6), Availability (F_7), Communication (F_8), and Cost (F_9).

Step 2. Develop a pairwise comparison matrix *PW* expressed in (1).

$$PW = \begin{bmatrix} PW_{11} & \cdots & PW_{1m} \\ PW_{21} & \cdots & PW_{2m} \\ \vdots & \cdots & \vdots \\ PW_{m1} & \cdots & PW_{mm} \end{bmatrix} \quad (1)$$

where PW_{tl} is a pairwise comparison between factor (row) t (F_t) and factor (column) l (F_l).

It may be easier for DMs to express their opinion on only two factors than simultaneously on all the factors [24]. By using the fundamental scales, provided in Table 1, DMs can perform pairwise comparisons of the factors with respect to the goal. For example, Table 1 shows that if Quality (F_4) is strongly more important than Cost (F_9), then $PW_{49} = 5$ and $PW_{94} = 1/5$. It can be concluded that $PW_{tl} = 1$ when $l = t$.

Step 3. Develop a normalized matrix in (3) by Eq. (2). Normally, the numbers in the first row of (1) are larger than the rest of the numbers indicating some inconsistency in the comparisons. Therefore, we normalize the numbers.

$$PW^*_{tl} = \frac{PW_{tl}}{\sum_l PW_{tl}} \qquad \forall lj \quad (2)$$

$$PW^* = \begin{bmatrix} PW^*_{11} & \cdots & PW^*_{1m} \\ PW^*_{21} & \cdots & PW^*_{1m} \\ \vdots & \cdots & \vdots \\ PW^*_{m1} & \cdots & PW^*_{mm} \end{bmatrix} \quad (3)$$

Step 4. Calculate the weight of each factor by Eq. (4).

$$W_j = \frac{\sum_{t=1}^{m} PW^{w*}_{tl}}{m} \quad (4)$$

B. Rank Vendors by TOPSIS

After determining the factors' weight by AHP, we now start evaluating the vendors against the factors by TOPSIS. In TOPSIS, developed by Hwang and Yoon [23], the best vendor should have the shortest distance from the positive ideal solution (PIS) and the farthest from the negative ideal solution (NIS). Assume that there are *n* vendors, $i = 1, 2, \ldots, n$, and *m* factors, $j = 1, 2, \ldots, m$.

Step 1. Construct the decision matrix *D* expressed in (5).

$$D = \begin{bmatrix} X_{11} & \cdots & X_{1n} \\ X_{21} & \cdots & X_{2n} \\ \vdots & \cdots & \vdots \\ X_{m1} & \cdots & X_{mn} \end{bmatrix} \quad (5)$$

where X_{ji} represent the score of the Vendor *i* on factor j.

Step 2. Normalize the decision matrix *D* in (7) by Eq. (6). This step transforms different units among the factors into a common measurable unit.

$$X^*_{ji} = \frac{x_{ji}}{\sqrt{\sum_i x_{ji}}} \qquad \forall ji \quad (6)$$

$$D^* = \begin{bmatrix} X^*_{11} & \cdots & X^*_{1n} \\ X^*_{21} & \cdots & X^*_{2n} \\ \vdots & \cdots & \vdots \\ X^*_{m1} & \cdots & X^*_{mn} \end{bmatrix} \quad (7)$$

Step 3. Construct the weighted normalize decision matrix in (9) by Eq. (8).

$$X^{w*}_{ji} = X^*_{ji} W_j \qquad \forall ji \quad (8)$$

$$D^{w*} = \begin{bmatrix} X^{w*}_{11} & \cdots & X^{w*}_{1n} \\ X^{w*}_{21} & \cdots & X^{w*}_{2n} \\ \vdots & \cdots & \vdots \\ X^{w*}_{m1} & \cdots & X^{w*}_{mn} \end{bmatrix} \quad (9)$$

In Eq. (8), $W_j \forall j$, is the relative importance of factor j, determined by AHP.

Step 4. Find the best, S^b, and the worst, S^w, possible vendors as the referential ones by Eqs. (10)-(11), respectively.

$$S^b = \{B_1, B_2, \cdots, B_m\} \quad (10)$$

$$S^w = \{N_1, N_2, \cdots, N_m\} \quad (11)$$

where $B_j = \min(X^{w*}_{j1}, \ldots, X^{w*}_{jn})\ \forall j$ and $N_j = \max(X^{w*}_{j1}, \ldots, X^{w*}_{jn})\ \forall j$ for cost attributes, $B_j = \max(X^{w*}_{j1}, \ldots, X^{w*}_{jn})\ \forall j$ and $N_j = \min(X^{w*}_{j1}, \ldots, X^{w*}_{jn})\ \forall j$ for benefit attributes.

Table 1. The fundamental scale [22]

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored, and its dominance demonstrated in practice
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
2, 4, 6, 8	Intermediate values between the two adjacent judgments	When compromise is needed
1/3, 1/5, 1/7, 1/9	Values for inverse comparison	

Step 5. Calculate the separation of each vendor from the best and the worst possible vendors by Eqs. (12)-(13), respectively.

$$S_i^+ = \sqrt{\sum_{j=1}^{m}(X_{ji}^{w*} - B_j)^2} \qquad \forall i \qquad (12)$$

$$S_i^- = \sqrt{\sum_{j=1}^{m}(X_{ji}^{w*} - N_j)^2} \qquad \forall i \qquad (13)$$

Step 6. The relative closeness to the ideal solution is calculated by Eq. (14) as follows

$$R_i = \frac{S_i^-}{S_i^+ + S_i^-} \qquad \forall i \qquad (14)$$

Sort the vendors in descending order of R_i. Larger R_i indicates larger distance from the worst possible vendor and closer to the best possible vendor.

IV. NUMERICAL ANALYSIS

Here, we assume that there are seven possible vendors who are evaluated against the nine aforementioned factors.

Use AHP to determine weight of factors

In Stage 1, we apply AHP to determine the factors' weight. We assume that the DMs use Table 1 to create a pairwise comparison matrix for the factors and present them in Table 2. Numbers in Table 2 are randomly generated by "RANDBETWEEN" function in Ms. Excel.

By Eq. (2), we normalize the pairwise matrix and present the result in Table 3.

Finally, the factors' weight is calculated by Eq. (4) as shown in Table 4.

One can see that Availability (F_7), Reputation (F_6) and Reliability (F_5) are the top three factors, and Cost (F_9) is the least important factor for the DMs. Now, we can move to the second stage and apply TOPSIS to evaluate and rank the vendors based on the nine factors.

Use TOPSIS to rank suppliers

To construct the decision matrix, we randomly generate the vendors' score for each factor by "RANDBETWEEN" function in Ms. Excel.

Now, we use Eq. (6) to normalize the decision matrix presented in Table 6.

Eq. (8) is used to incorporate the weight of each factor, obtained by AHP, into the evaluation process as presented in Table 7.

Here, we use Eqs. (10)-(11) to find the best, S^b, and the worst, S^w, possible vendors, and then use Eqs. (12)-(13) to calculate the separation of each vendor from them. Finally, we use Eq. (14) to compute the relative closeness of each vendor to the ideal solution as presented in Table 8.

Here, one can observe that Vendor 3 is the best one due to its performance, mainly on Availability (F_7), Reputation (F_6) and Reliability (F_5). We call the numerical example of this section as Case 1. To evaluate the effectiveness of the proposed model in incorporating the DMs' preferences in the decision process, we do the following sensitivity analysis.

Table 2. The pairwise comparison matrix

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
Capability (F_1)	1.00	3.00	5.00	1.00	0.20	0.33	0.14	3.00	0.14
Knowledge (F_2)	0.33	1.00	7.00	1.00	3.00	3.00	0.14	0.20	3.00
Longevity (F_3)	0.20	0.14	1.00	3.00	1.00	3.00	0.33	0.20	0.20
Product Quality (F_4)	1.00	1.00	0.33	1.00	3.00	5.00	0.33	0.20	5.00

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	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
Reliability (F_5)	5.00	0.33	1.00	0.33	1.00	5.00	1.00	3.00	3.00
Reputation (F_6)	3.00	0.33	0.33	0.20	0.20	1.00	3.00	5.00	7.00
Availability (F_7)	7.00	7.00	3.00	3.00	1.00	0.33	1.00	5.00	3.00
Communication (F_8)	0.33	5.00	3.00	3.00	0.33	0.20	0.20	1.00	3.00
Cost (F_9)	0.14	0.33	5.00	0.20	0.33	0.14	0.33	0.33	1.00
Sum	18.00	18.13	25.66	12.73	10.06	18.00	6.47	17.93	25.34

Table 3. The normalized pairwise matrix

	F_1	F_2	F_3	F_4	F_5	F_6	F_7	F_8	F_9
Capability (F_1)	0.056	0.165	0.195	0.079	0.020	0.018	0.022	0.167	0.006
Knowledge (F_2)	0.018	0.055	0.273	0.079	0.298	0.167	0.022	0.011	0.118
Longevity (F_3)	0.011	0.008	0.039	0.236	0.099	0.167	0.051	0.011	0.008
Product Quality (F_4)	0.056	0.055	0.013	0.079	0.298	0.278	0.051	0.011	0.197
Reliability (F_5)	0.278	0.018	0.039	0.026	0.099	0.278	0.155	0.167	0.118
Reputation (F_6)	0.167	0.018	0.013	0.016	0.020	0.056	0.464	0.279	0.276
Availability (F_7)	0.389	0.386	0.117	0.236	0.099	0.018	0.155	0.279	0.118
Communication (F_8)	0.018	0.276	0.117	0.236	0.033	0.011	0.031	0.056	0.118
Cost (F_9)	0.008	0.018	0.195	0.016	0.033	0.008	0.051	0.018	0.039

Table 4. The weight of the factors

Factors	Weight	Ranking
Capability (F_1)	0.081	7
Knowledge (F_2)	0.116	4
Longevity (F_3)	0.070	8
Product Quality (F_4)	0.115	5
Reliability (F_5)	0.131	3
Reputation (F_6)	0.145	2
Availability (F_7)	0.200	1
Communication (F_8)	0.100	6
Cost (F_9)	0.043	9

Table 5. The decision matrix generated in Ms. Excel

Factors	Weight	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Capability (F_1)	0.081	9.00	10.00	8.00	9.00	10.00	9.00	9.00
Knowledge (F_2)	0.116	0.00	81.00	88.00	30.00	17.00	63.00	84.00
Longevity (F_3)	0.070	0.75	0.70	0.53	0.45	0.24	0.48	0.24
Product Quality (F_4)	0.115	0.81	1.00	0.97	0.92	0.28	0.56	0.21
Reliability (F_5)	0.131	0.82	0.11	0.83	0.26	0.36	0.40	0.11
Reputation (F_6)	0.145	5.00	3.00	4.00	7.00	4.00	3.00	2.00
Availability (F_7)	0.200	10.00	8.00	8.00	9.00	9.00	8.00	9.00
Communication (F_8)	0.100	5.00	9.00	12.00	12.00	9.00	12.00	7.00
Cost (F_9)	0.043	19.00	20.00	7.00	5.00	18.00	19.00	19.00

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Table 6. The normalized decision matrix

Factors	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Capability (F_1)	0.371	0.412	0.330	0.371	0.412	0.37	0.37
Knowledge (F_2)	0.000	0.497	0.540	0.184	0.104	0.387	0.52
Longevity (F_3)	0.547	0.510	0.386	0.328	0.175	0.350	0.18
Product Quality (F_4)	0.411	0.508	0.492	0.467	0.142	0.284	0.11
Reliability (F_5)	0.621	0.083	0.629	0.197	0.273	0.303	0.083
Reputation (F_6)	0.442	0.265	0.354	0.619	0.354	0.265	0.177
Availability (F_7)	0.432	0.346	0.346	0.389	0.389	0.346	0.389
Communication (F_8)	0.193	0.348	0.464	0.464	0.348	0.464	0.271
Cost (F_9)	0.438	0.461	0.161	0.115	0.415	0.438	0.438

Table 7. The weighted normalized decision matrix

Factors	S_1	S_2	S_3	S_4	S_5	S_6	S_7
Capability (F_1)	0.030	0.033	0.027	0.030	0.033	0.030	0.030
Knowledge (F_2)	0.000	0.058	0.062	0.021	0.012	0.045	0.060
Longevity (F_3)	0.038	0.036	0.027	0.023	0.012	0.024	0.012
Product Quality (F_4)	0.047	0.059	0.057	0.054	0.016	0.033	0.012
Reliability (F_5)	0.081	0.011	0.082	0.026	0.036	0.040	0.011
Reputation (F_6)	0.064	0.039	0.051	0.090	0.051	0.039	0.026
Availability (F_7)	0.086	0.069	0.069	0.078	0.078	0.069	0.078
Communication (F_8)	0.019	0.035	0.046	0.046	0.035	0.046	0.027
Cost (F_9)	0.019	0.020	0.007	0.005	0.018	0.019	0.019

Table 8. Relative closeness of vendors to the ideal solution

	S_1	S_2	S_3	S_4	S_5	S_6	S_7
R_i	0.554	0.467	0.718	0.548	0.309	0.456	0.351
Vendors' Ranking	2	4	1	3	7	5	6

Perform Sensitivity Analysis

The DMs can incorporate their preferences or strategies in the decision process by assigning different weights to the factors. We do so by the following cases.

Case 2. In this case, we assume that Communication (F_8) and Cost (F_9) are the most important factors for the DMs, and thus, W_8 and W_9 are 0.465. The weight of the other factors is 0.01. TOPSIS is again used to calculate the vendors' relative closeness as follows:

	S_1	S_2	S_3	S_4	S_5	S_6	S_7
R_i	0.063	0.299	0.897	0.971	0.334	0.457	0.178
Vendors' Ranking	7	5	2	1	4	3	6

Here, one can see that Vendor 4 is the best because it has the highest score on Communication (F_8) and the lowest score on Cost (F_9).

Case 3. In this case, we set W_3 and W_5 to 0.465, and the others to 0.01. The vendors' relative closeness is calculated as follows:

	S_1	S_2	S_3	S_4	S_5	S_6	S_7
R_i	0.974	0.380	0.785	0.283	0.269	0.425	0.017
Vendors' Ranking	1	4	2	5	6	3	7

One can observe that Vendor 1 is the best one due to its performance on the third and fifth factors.

The three cases show that Vendor 3 is one of the top two vendors. By analyzing its scores and performance on F_3, F_5, F_6, F_7, F_8, and F_9, presented in Table 5, we can observe that it is one of the top vendors and the model accurately gives it a higher final score.

V. CONCLUSION

It is necessary to consider all of the resources and options available to optimize the efficient implementation of AI. After all, AI is not a magic solution, and will only produce results equal to the planning and preparation of an organization. The question framework we developed for the make or buy decision can help businesses determine their best course of action. Overall, the decision will boil down to

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the strategic importance of the project and the contribution to operational performance for a given firm. Once [if] a firm decides they want to outsource the execution of a given project, the selection of the best vendor is critical. The question framework for vendor selection can be a helpful tool for determining the criteria and requirements of vendors' comparison. Once the DMs are in agreement of the criteria, AHP and TOPSIS analysis can help facilitate the accurate evaluation of the potential vendors.

The limitations of this paper include the narrow scope given the research stayed theoretical within our application of the AHP and TOPSIS method. Instead of identifying real vendors, we created fictional vendors and data to test the utilization of the guide we developed. Future research could explore specific AI adoption decisions and apply the make or buy framework to real data and vendors.

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