*Journal of Computer & Robotics 17 (1), Winter and Spring 2024, 35-46*

Computer & Robotics

# Identifying and Ranking the Criteria of Outsourcing Capabilities of Maintenance Activities and Analyzing the Profitability of Outsourcing Using Bayesian BWM

Hamid Esmaili [a], Hossein Kaveh Pishghadam [a,*]

[a] *Department of Industrial Engineering, North Tehran Branch, Islamic Azad University, Tehran, Iran*

Received 25 April 2023; Accepted 13 September 2023


## Abstract

Outsourcing of corporate activities by suppliers has long been done in the oil and gas industry. Outsourcing is known as a tool to gain strategic advantages. Outsourcing maintenance is also a common practice in many industries, including producing chemicals, petroleum, petrochemicals, and medical equipment. However, this process involves many risks, with their extent and nature still unclear. There are strong reasons for outsourcing some of the most important economic concepts. Determining the effective indicators in this selection and the importance and priority of each of them has always been the subject of intense research. In this paper, we examined the effects of these variables and assessed their relationship with decision-making outsourcing maintenance at gas refineries. First, the effective variables were identified by reviewing the literature and based on experts' opinions. Next, it was tried to prioritize the indicators identified from previous studies using the relatively new Bayesian Best-Worst method (BWM). The results are then compared using one of the most recent decision-making methods, i.e., the Ordinal Priority Approach. Comparing the results of these two models shows that in both models, the cost of technology modernization and upgrades, the cost of emergency repairs and production stops, the cost of depreciation of equipment and machinery, and the cost of major repairs are the top four significant criteria among all the examined ones. However, the first and second methods consider "cost of maintenance" and "cost of productivity" more significant, respectively. It is worth noting that other differences were also identified in this study.


***Keywords:*** Priority; Outsourcing; Maintenance; Best-Worst Method; Order Priority Approach

## 1.Introduction

Outsourcing has become a major trend in human resources over the past decade. This process refers to having certain job functions done out-house instead of in-house. Nowadays, a larger number of companies, whether large or small, have resorted to outsourcing as a technique to grow their business while maintaining salaries and overhead costs1. Outsourcing (sometimes referred to as "contracting") is the delivery of the tasks, operations, jobs, or processes of a force or work team under a contract to a third party for a specified period of time2. Businesses usually do outsourcing to lower their costs or improve their efficiency. Outsourced functions can be performed by a third party in-house or out-house. Sometimes a company experiences growth at a rate that it cannot support with its internal staff3. To keep up the pace, the firm can hire a pre-trained workforce from a third-party firm to deploy as needed and where needed in its operations without interrupting its business flow4. In addition, a company may have processes that occur only for a short period of time, making it much more efficient to hire a temporary team and outsource workers to complete the work. If the company implements a new process, it can train the job to workers rather than investing time, money, and effort into training and retaining internal workers5. Furthermore, outsourcing companies often provide management-level employees with their work teams, thus freeing

[1] . Rezaeisaray
[2] . Van Kien, P., & Moslehpour
[3] . Kaur
[4] . Erdoğan, M., & Kaya
[5] . Yadav

[*] Corresponding Author. Email: kaveh.pishghadam@yahoo.com

up internal employees to do other work. On the other hand, conventional wisdom about the outsourcing decision states that you should choose to outsource your "non-core" business activities. However, the problem with this approach is that it offers no guidance for making decisions about "non-core" activities6.

Rezaeisaray et al.7 developed a new hybrid MCDM approach for outsourcing supplier selection, Van Kien & Moslehpour [8] specified multiple criteria for the service outsourcing model through MCDM. In [9], Kaur et al. modeled joint outsourcing and offshoring decision integrated with fuzzy-MCDM approaches. Erdoğan & Kaya [10] made an effort to select the best outsourcing firm for WEEE in a hesitant fuzzy environment. Yadav et al. [11] presented a hybrid BWM-ELECTRE-based decision-making framework for effective offshore outsourcing adoption. Other researchers have also used different MCDM techniques in their research, such as Yadav et al. [12], Kahraman et al. [13], Barak and Javanmard [14], and Ji et al. [15].

Blair et al. (2022) emphasized the importance of the characteristics and context of the organization. The reason for outsourcing is mainly the supply of certain products or services that the organization prefers not to produce for various reasons. The form of the contract between the provider and the client was also studied to identify key features. Moreover, a global sourcing option was considered in this study. [16].

Kiani et al. (2022) investigated outsourcing activities through fuzzy multi-criteria decision-making techniques. After reviewing the available documents and identifying 9 outsourcing activities, they collected data for analysis through a questionnaire sent to experts. Then, the data were prioritized through fuzzy SAW, fuzzy TOPSIS, and fuzzy VIKOR. Finally, as these methods produced contradictory results, techniques such as mean rank, Burda, and Copeland were used to reach a consensus. This study proposed a model for ranking outsourcing activities, according to which decision-makers and researchers should consider multiple criteria and several methods simultaneously to select outsourcing activities. [17]. To focus on their core skills and be more competitive and efficient in business, companies often outsource their logistics tasks to a third-party logistics (3PL) provider. Evaluating and selecting a 3PL provider is a multi-criteria decision-making process since it involves considering a variety of competitive qualitative and quantitative criteria. According to Boakani and Samanlioglu (2023), as the MCDM method, the fuzzy best-worst method (FBWM) is used for the 3PL provider selection problem of a textile company in Turkey. In this method, 6 3PL provider alternatives are evaluated by decision-makers in terms of 15 criteria. It combines decision makers' imprecision and ambiguity into the decision-making process and requires fewer pairwise comparisons than the method commonly used in 3PL provider selection, i.e., the fuzzy analytic hierarchy process (FAHP). Consistent results are always obtained when using fuzzy BWM, though not fully consistent. [18].

Igodo et al. (2023) found that the quality, lead time, price, and severity of spare part failure are the key criteria to consider when selecting spare parts for the WtE plant. They recommended several initiatives to improve the availability of the WtE plant and spare parts to reduce the maintenance cost and mitigate the risks related to the maintenance. [19].

After determining the factors affecting outsourcing and its effects, the researchers had a literature review and then prioritized the indicators using the new Bayesian best-worst method (BWM). Next, they confirmed the results using the newly presented ordinal priority approach. Overall, determining priorities can help decision-makers toward more reliable and profitable outsourcing.

## 2.Materials and Methods

This study uses the Bayesian BWM and compares its outputs with those of the OPA method. These methods are introduced in the following.

BWM: Multi-criteria decision-making (MCDM) is an essential branch of decision-making theory. MCDM problems are generally divided into two classes with respect to the solution space of the problem: continuous and discrete. MODM methods are used to handle continuous problems. On the other hand, discrete problems are solved using multi-attribute decision-making methods (MADM). One of these methods is the best-worst method (BWM), in which the best and worst criteria are first selected. Pairwise comparisons are then conducted between these two criteria (best and worst) and the other criteria, giving a structure to the problem. BWM has 5 main steps: [20]

o Step 1: Determining a set of decision criteria

o Step 2: Determining the best and worst criteria

[6] . Kahraman

[7] . Barak, S., & Javanmard

o Step 3: Determining the preference of the best criterion over all the other criteria using a number between 1 and 9: The result would be the Best-to-Others (BO) vector. Here, $A_B = [a_{B1}, a_{B2}, \ldots, a_{Bn}]$ shows the preference of the best criterion B over criterion j.

o Step 4: Determining the preference of all the criteria over the worst criterion using a number between 1 and 9: The result would be the Others-to-Worst (OW) vector $A_W = (a_{w1}, a_{w2}, \ldots, a_{wn})^T$. Here, $a_{wj}$ denotes the priority of criterion j over the worst criterion w.

o Step 5: Finding the optimal weight: The criterion's optimal weight should be determined to minimize the difference between all the criteria. The sum of the weights must be 1. In addition, the weights should not be negative. This step is expressed by the Min-Max model below:

$$\text{min-max}_j = \left\{ \left| \frac{w_B}{w_j} - a_{Bj} \right|, \left| \frac{w_j}{w_w} - a_{jw} \right| \right\} \tag{1}$$

so that:

$$\begin{gathered} \sum W_j = 1 \\ 2\; w_j \geq 0, \text{for all j} \end{gathered} \tag{2}$$

To solve this problem, we can use linear programming. The Min-Max model can be modified as follows:

$$\begin{aligned} &\min \quad \xi \\ &\left| \frac{W_B}{W_j} - a_{Bj} \right| \leq \xi \text{ for all j} \\ &\left| \frac{W_j}{W_w} - a_{jw} \right| \leq \xi \text{ for all j} \\ &\sum W_j = 1 \\ &w_j \geq 0, \text{for all j} \end{aligned} \tag{3}$$

By solving this problem, we obtain the optimal weights $\xi^*$. Here, $\xi^*$ shows the reliability of the weights based on the continuity of comparisons. The closer it is to 0, the more reliable and consistent the comparisons are. Complete continuity for all j is achieved when $a_{Bj} \times a_{jw} = a^*_{Bj}$.

**3.Bayesian Best-worst Model**

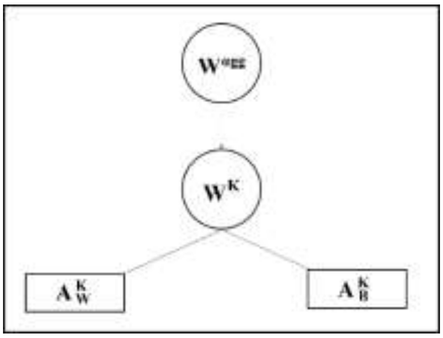


Fig. 1. Probabilistic graphical model of Bayesian BWM

According to Mohammadi and Rezaei [21], developing a Bayesian model involves first identifying the independence and conditional independence of the variables. Fig. 1 illustrates the graphical models related to the model. The nodes in the diagram are the variables. As a convention, rectangles are the observed variables, which are the main inputs to BWM. The circular nodes are variables that should be estimated. Also, the arrow denotes that the node at the origin depends on the node at the other end. In other words, the value of $W^k$ depends on $A_w^k$ and $A_B^k$. Also, the value of $W^{\propto gg}$ depends on $W^k$. The page, which contains a set of variables, means that the relevant variables are repeated for each decision and $W^{\propto gg}$ is not on the page because there is only one $W^{\propto gg}$ for the decision. Conditional independence between different variables is shown in Fig. 1. For instance, $A_w^k$ depends on $W^k$, which itself is from $W^{\propto gg}$, that is,

$$P(A_W^K \mid W^{\propto gg}, W^K) = (A_W^K \mid W^K) \tag{4}$$

Considering all the independence between different variables, applying the Bayesian rule to the joint probability is given by Eq. (5):

$$P(W^{\propto gg}, W^{1:K} \mid A_B^{1:K}, A_W^{1:K}) \propto$$
$$P(A_B^{1:K}, A_W^{1:K} \mid W^{\propto gg}, W^{1:K}) P(W^{\propto gg}, W^{1:K}) =$$
$$P(W^{\propto gg}) \prod_{K=1}^{K} P(A_W^K \mid W^K) P(A_B^K) \tag{5}$$
$$(W^K \mid W^{\propto gg})$$

where the last equality is obtained using the probability chain rule and the conditional independence of different variables. Here, each decision-maker independently provides its own priorities. Since estimating the parameters in Eq. (5) relies on estimating other variables, there is a chain between different parameters, which is why this model is called hierarchical. The only difference between $A_B$ and $A_W$ is that the former indicates the priority of all criteria in the worst conditions. In contrast, the latter shows the priority of the best criterion in all other criteria.

OPA method: This method is used to determine the numerical weights of decision alternatives by experts based on a set of attributes. Most group decision-making techniques provide a ranking system for prioritizing the alternatives without considering the preference of the alternatives over one another. Some other methods for group decision-making first calculate the weights of the attributes by determining the decision-making attributes, followed by ranking the alternatives by aggregating the experts' opinions based on the attributes. However, alternatives, attributes, and experts can be used simultaneously as three sides of the decision triangle to determine their importance. Fig. 2 provides a diagrammatic representation of the decision-making triangle. In this method, the characteristics of each side are simultaneously considered for decision-making issues [22].

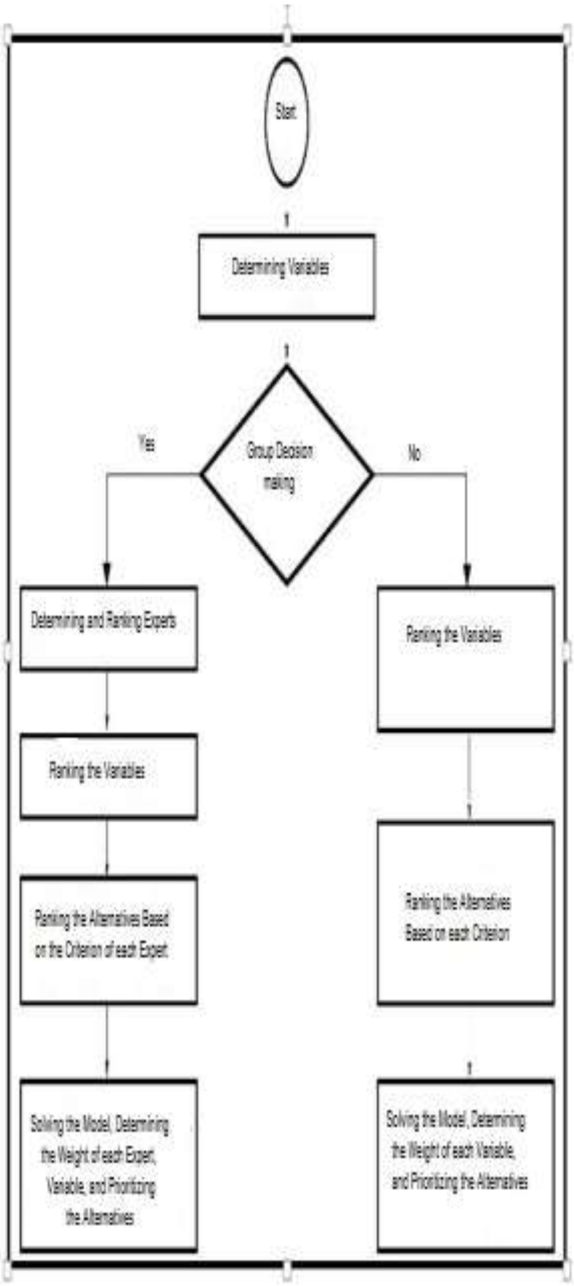


Fig. 2. Diagrammatic representation of the decision-making triangle (ibid)

Key variables were extracted in this study using the data reported from previous studies in the first stage and the opinion of experts in the second stage. Table 1 gives the key variables in modeling the research problem. In the next step, each criterion and sub-criterion's importance was determined and ranked using the Bayesian BWM. These indicators are divided into 4 categories.

Table 1
Key influential variables in the outsourcing of maintenance operation

| Row | | Indicators |
|---|---|---|
| EC1 | General Expenses | Cost of basic raw materials |
| EC2 | | Cost of producing non-standard or poor-quality products |
| EC3 | | Cost of outsourcing |
| EC4 | | Cost of spare parts and consumables |
| EC5 | | Cost of storing tools and equipment |
| EC6 | | Cost of equipment, tools, and machines |
| EC7 | | Cost of process errors |
| EC8 | | Cost of defective products |
| MC1 | Maintenance expenses | Cost of human resources and maintenance |
| MC2 | | Cost of human resource training and maintenance |
| MC3 | | Cost of depreciation of equipment and machinery |
| MC4 | | Cost ofemergency repairs and production stops |
| MC5 | | Cost of overhaul and periodic repairs |
| MC6 | | Cost of technology modernization and upgrades |
| MC7 | | Cost of lost production due to emergency shutdowns |
| MC8 | | Cost of production stops during major and periodic repairs |
| EF1 | Variables related to productivity | Sales rate and customer satisfaction |
| EF2 | | Production rate of final high-quality products |
| EF3 | | Equipment efficiency rate |
| EF4 | | The effectiveness rate of the outsourced activity |
| EF5 | | Equipment availability rate |
| EF6 | | Profitability |
| EF7 | | Efficiency |
| EF8 | | The effectiveness rate of the equipment |
| OP1 | Other Variables | Average time to fix failures |
| OP2 | | The volume of outsourced activities |
| OP3 | | Operational and executive risks |
| OP4 | | Efficiency percentage of supply chain management |
| OP5 | | Efficiency percentage of products business and sales management |
| OP6 | | Freeing up resources for other purposes of the organization |
| OP7 | | Average cost price |
| OP8 | | Duration of equipment operation and failure |

Then, data were obtained for four main variables and sub-variables using the opinions of eleven experts and based on nine qualitative spectrums presented in Table 2.

The Bayesian BWM was formed in this step, and the criteria's weights were calculated by solving the model. Next, the weights were compared, and each criterion's importance and sub-criterion were determined and ranked using the Bayesian BWM. Finally, the best and worst criteria were obtained, the results of which are given in Table 3.

Table 2
Evaluation Scale

| Verbal phrases | Value |
|---|---|
| Equal importance | 1 |
| Of very little importance | 2 |
| Of little importance | 3 |
| Preferably important | 4 |
| Average importance | 5 |
| Moderately important | 6 |
| Very important | 7 |
| Absolutely important | 8 |

Table 3
Best and worst sub-variables

| Most important indicator | | Least important indicator | |
|---|---|---|---|
| 6.87 | EC3 | 4.20 | EC4 |
| 5.80 | MC6 | 4.13 | MC2 |
| 5.60 | EF6 | 3.60 | EF5 |
| 6.47 | OP5 | 4.07 | OP4 |

According to the results, "the cost of outsourcing" in the "General Expenses" category, "the cost of technology modernization and upgrades" in the "Cost of Maintenance" category, "profitability" in the "Productivity" category and "the efficiency percentage of products business and sales management" in the "Other Variables category were the most important indicators. On the other hand, "the cost of spare parts and consumables" in the "General Expenses" category, "cost of human resource training and maintenance" in the "Cost of Maintenance" category, "equipment availability rate" in the "Productivity" category, and "the efficiency percentage of supply chain management" were the least important criteria. In the next step, the degree of preference for the best criterion over the other criteria and the degree of preference of all criteria over the worst criterion were obtained. The results are given in Table 4.

Table 4
Degree of preference of the best criterion over the other criteria and the preference of all criteria over the worst criterion

| Variable | Degree of preference of the best criterion over the other criteria | Degree of preference of all criteria over the worst criterion |
|---|---|---|
| EC1 | 5 | 5 |
| EC2 | 6 | 4 |
| EC3 | 1 | 9 |
| EC4 | 9 | 1 |
| EC5 | 3 | 7 |
| EC6 | 4 | 6 |
| EC7 | 2 | 8 |
| EC8 | 4 | 6 |
| MC1 | 5 | 5 |
| MC2 | 9 | 1 |
| MC3 | 3 | 7 |
| MC4 | 2 | 8 |
| MC5 | 4 | 6 |
| MC6 | 1 | 9 |
| MC7 | 7 | 3 |
| MC8 | 6 | 4 |
| EF1 | 2 | 8 |
| EF2 | 3 | 7 |
| EF3 | 8 | 2 |
| EF4 | 4 | 6 |
| EF5 | 9 | 1 |
| EF6 | 1 | 9 |
| EF7 | 5 | 5 |
| EF8 | 6 | 4 |
| OP1 | 8 | 2 |
| OP2 | 3 | 7 |
| OP3 | 4 | 6 |
| OP4 | 9 | 1 |
| OP5 | 1 | 9 |
| OP6 | 5 | 5 |
| OP7 | 6 | 4 |
| OP8 | 6 | 4 |

Then, the weight of each of the sub-variables was calculated. The results are presented in Table 5:

Table 5
Weights of the sub-variables

| Symbol | W | Symbol | W |
|---|---|---|---|
| EC1 | 0.0293 | EF1 | 0.0300 |
| EC2 | 0.0285 | EF2 | 0.0296 |
| EC3 | 0.0425 | EF3 | 0.0208 |
| EC4 | 0.0260 | EF4 | 0.0304 |
| EC5 | 0.0314 | EF5 | 0.0235 |
| EC6 | 0.0297 | EF6 | 0.0323 |
| EC7 | 0.0330 | EF7 | 0.0273 |
| EC8 | 0.0297 | EF8 | 0.0262 |
| MC1 | 0.0446 | OP1 | 0.0150 |
| MC2 | 0.0401 | OP2 | 0.0197 |
| MC3 | 0.0498 | OP3 | 0.0195 |
| MC4 | 0.0549 | OP4 | 0.0170 |
| MC5 | 0.0478 | OP5 | 0.0239 |
| MC6 | 0.0562 | OP6 | 0.0185 |
| MC7 | 0.0433 | OP7 | 0.0182 |
| MC8 | 0.0433 | OP8 | 0.0182 |

Fig.3 presents the graph of the weights calculated for each sub-variable in the BWM method.
Finally, the compatibility rate and index were obtained for each main variable (Table 6).

Table 6
Compatibility rate and index

| | | |
|---|---|---|
| **General Expenses** | **Compatibility index** | ٥,٢٣ |
| | $\Xi$ | ٠,٤٧٤ |
| | Compatibility rate | ٠,٠٩١ |
| Cost of Maintenance | Compatibility index | ٤,٤٧ |
| | $\Xi$ | ٠,٤٢٨ |
| | Compatibility rate | ٠,٠٩٦ |
| Variables related to | Compatibility index | ٤,٩١ |
| | $\Xi$ | ٠,٤٣٥ |
| | Compatibility rate | ٠,٠٩٣ |
| Other Variab | Compatibility index | ٥,١٣ |
| | $\Xi$ | ٠,٤٦٥ |

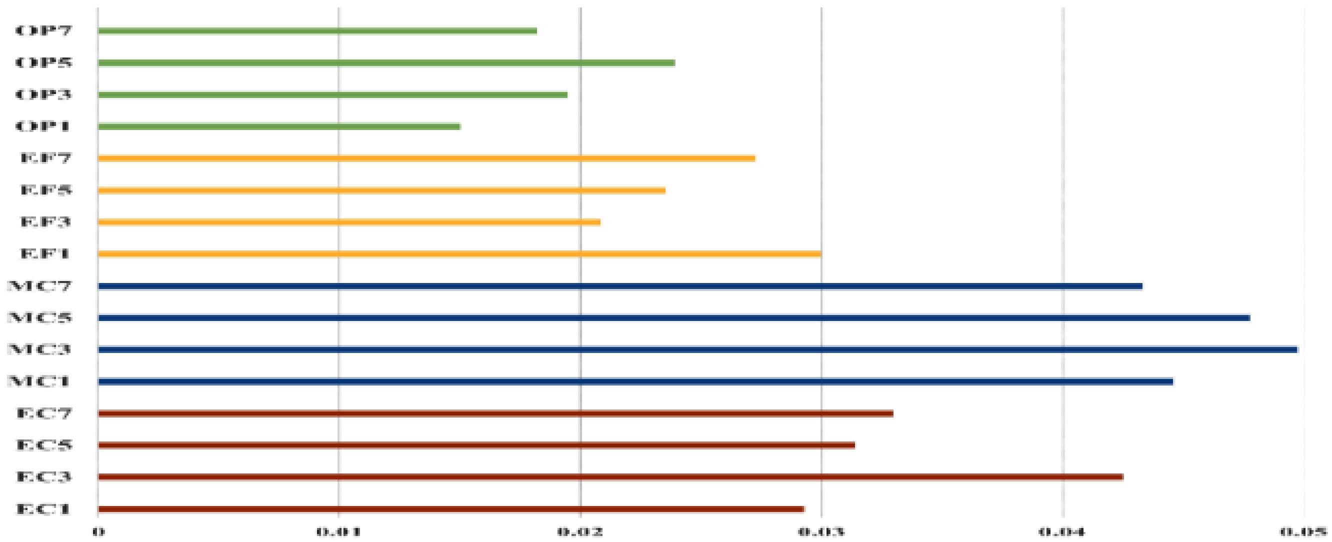


Fig. 3 Weights of the variables

This project aimed to prioritize the decision based on the variables of 4 categories. In the first step, the weight of each variable was calculated (using the Bayesian BWM) as listed in Table 5. In the next step, the results were analyzed using the OPA method. For this purpose, the variables affecting the model were determined, as given in Table 1. Afterward, the experts participating in the decision-making process were identified and ranked based on several factors, including an organizational chart, experience, and level of training. The ranks of 11 experts determined in this research are given in Table 7.

Table 7
Ranks of the experts

| Expert No. | Rank | Expert No. | Rank |
|---|---|---|---|
| 1 | 2 | 7 | 9 |
| 2 | 6 | 8 | 4 |
| 3 | 3 | 9 | 11 |
| 4 | 1 | 10 | 8 |
| 5 | 7 | 11 | 5 |

In the next step, the experts prioritized the attributes based on their expertise. If some experts found certain attributes not critical or lacked sufficient knowledge to comment on incorporating a certain attribute, they were free to consider it in the ranking method and the mathematical model. Additionally, some attributes may have the same priority for an expert. These ranks are reflected with similar priority in the prioritization process. The priority of each expert is specified in Table.

Table 8
Priority of the experts

| Variables | Expert 1 | Expert 2 | Expert 3 | Expert 4 | Expert 5 | Expert 6 | Expert 7 | Expert 8 | Expert 9 | Expert 10 | Expert 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EC1 | 12 | 13 | 30 | 15 | 4 | 4 | 21 | 4 | 22 | 18 | 5 |
| EC2 | 11 | 4 | 5 | 7 | 29 | 25 | 22 | 17 | 26 | 9 | 11 |
| EC3 | 7 | 6 | 2 | 4 | 4 | 15 | 7 | 3 | 2 | 17 | 15 |
| EC4 | 14 | 22 | 28 | 17 | 32 | 2 | 9 | 17 | 15 | 10 | 3 |
| EC5 | 20 | 9 | 5 | 8 | 25 | 9 | 6 | 21 | 9 | 13 | 15 |
| EC6 | 5 | 22 | 6 | 22 | 24 | 27 | 30 | 23 | 16 | 30 | 31 |
| EC7 | 21 | 30 | 18 | 8 | 12 | 2 | 21 | 2 | 12 | 25 | 6 |
| EC8 | 10 | 1 | 13 | 4 | 11 | 7 | 13 | 32 | 19 | 21 | 20 |
| MC1 | 3 | 15 | 15 | 26 | 9 | 26 | 7 | 18 | 6 | 20 | 5 |
| MC2 | 19 | 28 | 9 | 12 | 3 | 17 | 15 | 19 | 7 | 6 | 18 |
| MC3 | 19 | 19 | 25 | 18 | 27 | 4 | 19 | 2 | 6 | 27 | 20 |
| MC4 | 27 | 20 | 31 | 31 | 32 | 28 | 3 | 29 | 4 | 8 | 5 |
| MC5 | 13 | 27 | 28 | 31 | 11 | 30 | 30 | 21 | 15 | 14 | 2 |
| MC6 | 28 | 17 | 16 | 1 | 5 | 11 | 18 | 22 | 9 | 18 | 9 |
| MC7 | 28 | 1 | 16 | 28 | 9 | 7 | 15 | 15 | 3 | 5 | 20 |
| MC8 | 25 | 30 | 8 | 12 | 4 | 2 | 26 | 15 | 25 | 4 | 15 |
| EF1 | 2 | 28 | 23 | 3 | 7 | 30 | 9 | 2 | 24 | 11 | 27 |
| EF2 | 6 | 20 | 24 | 27 | 12 | 32 | 4 | 23 | 4 | 18 | 7 |
| EF3 | 18 | 29 | 13 | 4 | 23 | 7 | 19 | 17 | 27 | 7 | 31 |
| EF4 | 18 | 32 | 15 | 13 | 4 | 7 | 29 | 25 | 28 | 15 | 23 |
| EF5 | 4 | 29 | 11 | 20 | 15 | 28 | 10 | 27 | 12 | 9 | 21 |
| EF6 | 25 | 28 | 19 | 23 | 3 | 11 | 5 | 4 | 8 | 1 | 1 |
| EF7 | 5 | 13 | 27 | 12 | 7 | 6 | 28 | 11 | 30 | 4 | 9 |
| EF8 | 20 | 4 | 20 | 21 | 4 | 8 | 10 | 17 | 7 | 29 | 18 |
| OP1 | 28 | 23 | 29 | 28 | 7 | 27 | 29 | 20 | 24 | 19 | 17 |
| OP2 | 20 | 19 | 24 | 5 | 1 | 22 | 29 | 29 | 20 | 16 | 15 |
| OP3 | 26 | 20 | 4 | 21 | 4 | 6 | 9 | 32 | 6 | 25 | 8 |
| OP4 | 10 | 16 | 2 | 25 | 18 | 8 | 28 | 6 | 5 | 27 | 32 |
| OP5 | 29 | 25 | 20 | 25 | 12 | 8 | 19 | 16 | 12 | 10 | 13 |
| OP6 | 10 | 28 | 23 | 25 | 19 | 19 | 30 | 17 | 24 | 10 | 7 |
| OP7 | 9 | 8 | 22 | 32 | 9 | 9 | 26 | 31 | 22 | 19 | 1 |
| OP8 | 6 | 14 | 15 | 17 | 31 | 25 | 7 | 30 | 16 | 13 | 14 |

In the fourth step, the rank of each alternative in each attribute was determined. The experts were asked to rank the alternatives for each attribute, even though some alternatives may have similar preferences for certain attributes. Table 9 presents the prioritization of the experts' alternatives. In the last step, the weight of each variable was calculated based on the priorities determined by 11 experts. The results are given in Table 10.

Table 9
Priority of the experts' alternatives

| Variables | Expert 1 | Expert 2 | Expert 3 | Expert 4 | Expert 5 | Expert 6 | Expert 7 | Expert 8 | Expert 9 | Expert 10 | Expert 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| EC1 | 30 | 19 | 14 | 8 | 29 | 14 | 7 | 27 | 23 | 16 | 18 |
| EC2 | 18 | 24 | 3 | 28 | 31 | 25 | 27 | 2 | 3 | 32 | 32 |
| EC3 | 8 | 32 | 5 | 9 | 18 | 29 | 28 | 1 | 10 | 32 | 13 |
| EC4 | 8 | 21 | 4 | 20 | 7 | 7 | 24 | 19 | 27 | 30 | 18 |
| EC5 | 28 | 1 | 27 | 8 | 23 | 12 | 11 | 23 | 31 | 2 | 27 |
| EC6 | 21 | 26 | 5 | 28 | 2 | 27 | 4 | 6 | 17 | 11 | 13 |
| EC7 | 3 | 27 | 31 | 11 | 9 | 21 | 9 | 9 | 3 | 6 | 26 |
| EC8 | 8 | 17 | 21 | 2 | 11 | 11 | 22 | 20 | 1 | 18 | 31 |
| MC1 | 21 | 31 | 8 | 4 | 16 | 28 | 28 | 6 | 30 | 4 | 27 |
| MC2 | 3 | 3 | 10 | 18 | 23 | 12 | 26 | 18 | 8 | 13 | 28 |
| MC3 | 31 | 26 | 5 | 1 | 20 | 5 | 22 | 14 | 9 | 25 | 4 |
| MC4 | 13 | 5 | 21 | 12 | 4 | 7 | 18 | 18 | 15 | 18 | 24 |
| MC5 | 14 | 12 | 1 | 31 | 20 | 20 | 19 | 27 | 10 | 9 | 32 |
| MC6 | 25 | 20 | 1 | 8 | 13 | 27 | 16 | 12 | 5 | 5 | 14 |
| MC7 | 15 | 24 | 14 | 12 | 31 | 8 | 18 | 21 | 13 | 26 | 27 |
| MC8 | 28 | 10 | 9 | 4 | 12 | 12 | 29 | 22 | 7 | 3 | 23 |
| EF1 | 9 | 20 | 5 | 27 | 19 | 28 | 19 | 30 | 10 | 1 | 26 |
| EF2 | 29 | 3 | 13 | 14 | 2 | 14 | 25 | 4 | 24 | 9 | 26 |
| EF3 | 10 | 15 | 17 | 17 | 23 | 2 | 23 | 15 | 32 | 29 | 12 |
| EF4 | 29 | 23 | 20 | 22 | 19 | 29 | 4 | 7 | 26 | 6 | 11 |
| EF5 | 24 | 4 | 27 | 10 | 9 | 13 | 23 | 12 | 14 | 27 | 23 |
| EF6 | 18 | 10 | 2 | 27 | 2 | 20 | 1 | 14 | 5 | 10 | 28 |
| EF7 | 18 | 26 | 9 | 26 | 22 | 2 | 4 | 16 | 7 | 22 | 17 |
| EF8 | 1 | 21 | 23 | 12 | 14 | 19 | 18 | 12 | 32 | 25 | 17 |
| OP1 | 29 | 23 | 4 | 18 | 15 | 27 | 29 | 9 | 17 | 22 | 2 |
| OP2 | 31 | 25 | 27 | 2 | 15 | 32 | 20 | 24 | 31 | 9 | 26 |
| OP3 | 27 | 31 | 32 | 28 | 32 | 16 | 15 | 22 | 9 | 22 | 25 |
| OP4 | 9 | 26 | 2 | 16 | 20 | 30 | 12 | 25 | 11 | 11 | 5 |
| OP5 | 21 | 15 | 11 | 30 | 3 | 27 | 21 | 30 | 4 | 28 | 15 |
| OP6 | 31 | 4 | 23 | 14 | 31 | 19 | 1 | 18 | 21 | 23 | 1 |
| OP7 | 27 | 23 | 32 | 20 | 21 | 15 | 21 | 9 | 3 | 6 | 23 |
| OP8 | 5 | 2 | 31 | 28 | 4 | 16 | 6 | 25 | 13 | 12 | 25 |

Table 10
Weights of the sub-variables calculated using the OPA method

| Symbol | W | Symbol | W |
|---|---|---|---|
| EC1 | 0.033977 | EF1 | 0.023479 |
| EC2 | 0.03302 | EF2 | 0.02287 |
| EC3 | 0.04929 | EF3 | 0.016049 |
| EC4 | 0.03455 | EF4 | 0.023182 |
| EC5 | 0.03637 | EF5 | 0.016049 |
| EC6 | 0.034455 | EF6 | 0.024965 |
| EC7 | 0.038284 | EF7 | 0.021101 |
| EC8 | 0.0301149 | EF8 | 0.02021 |
| MC1 | 0.048108 | OP1 | 0.017079 |
| MC2 | 0.043228 | OP2 | 0.013022 |
| MC3 | 0.053686 | OP3 | 0.016865 |
| MC4 | 0.059264 | OP4 | 0.01473 |
| MC5 | 0.051594 | OP5 | 0.020708 |
| MC6 | 0.060658 | OP6 | 0.015798 |
| MC7 | 0.046714 | OP7 | 0.016011 |
| MC8 | 0.046749 | OP8 | 0.015787 |

## 4.Discussion and Conclusion

Critical issues are overshadowed by outsourcing in any industry. Since outsourcing contributes much to the success of businesses, it is very important to find and prioritize the key factors affecting it. Therefore, this study was an attempt to determine the priority of indicators affecting the outsourcing of the maintenance operation and analyze the profitability of outsourcing using the Bayesian BWM and comparing its results with the results of the OPA method. After solving the problem using the Bayesian BWM and determining the weights of the parameters and their category, the priority of the parameters was determined. The results are given in Table 11. The results revealed that the most important factors affecting outsourcing and its profitability using this method were “the cost of technology modernization and upgrades”, “the cost of emergency repairs and production stops”, “the cost of depreciation of equipment and machinery”, “the cost of the overhaul and periodic repairs”, and “the cost of human resources and maintenance”. The results of the OPA method in Table 12 shows that the most important factors affecting outsourcing and its profitability are “the cost of technology modernization and upgrades”, “the cost of emergency repairs and production stops”, “the cost of depreciation of equipment and machinery”, “the cost of the overhaul and periodic repairs”, and “the cost of outsourcing”.

Comparing the two methods demonstrates that the first 4 variables had the highest priorities in both methods, except that the fifth priority in the Bayesian BWM is “the cost of human resources and maintenance”, while it is “the cost of outsourcing” in the OPA method. Considering the results of this research, future researchers are recommended to design the basic strategies required to achieve the optimal condition in the prioritized variables determined in this research. Future research can also focus on the variables related to the professional skill of the service providers.

Table 11
Priority of the variables obtained using the Bayesian BWM

| Variables | Final Weight | Priority | Variables | Final Weight | Priority |
|---|---|---|---|---|---|
| MC6 | 0.05622 | 1 | EF2 | 0.029596 | 17 |
| MC4 | 0.054927 | 3 | EC1 | 0.02929 | 18 |
| MC3 | 0.049758 | 3 | EC2 | 0.028465 | 19 |
| MC5 | 0.047819 | 4 | EF7 | 0.027308 | 20 |
| MC1 | 0.044588 | 5 | EF8 | 0.026154 | 21 |
| MC7 | 0043325 | 6 | EC4 | 0.02599 | 22 |
| MC8 | 0.043296 | 7 | OP5 | 0.023894 | 23 |
| EC3 | 0.042492 | 8 | EF5 | 0.023481 | 24 |
| MC2 | 0.040065 | 9 | EF3 | 0.020769 | 25 |
| EC7 | 0.033003 | 10 | OP2 | 0.019706 | 26 |
| EF6 | 0.032308 | 11 | OP3 | 0.01946 | 27 |
| EC5 | 0.031353 | 12 | OP6 | 0.018474 | 28 |
| EF4 | 0.030385 | 13 | OP7 | 0.018228 | 29 |
| EF1 | 0.03 | 14 | OP8 | 0.018216 | 30 |
| EC6 | 0.029703 | 15 | OP4 | 0.016996 | 31 |
| EC8 | 0.029703 | 16 | OP1 | 0.015026 | 32 |

Table 12
Priority of the variables obtained using the OPA method

| Variables | Final Weight | Priority | Variables | Final Weight | Priority |
|---|---|---|---|---|---|
| MC6 | 0.060658 | 1 | EF6 | 0.024965 | 17 |
| MC4 | 0.059264 | 2 | EF1 | 0.023479 | 18 |
| MC3 | 0.053686 | 3 | EF4 | 0.023182 | 19 |
| MC5 | 0.051594 | 4 | EF2 | 0.02287 | 20 |
| EC3 | 0.04929 | 5 | EF7 | 0.021101 | 21 |
| MC1 | 0.048108 | 6 | OP5 | 0.020708 | 22 |
| MC8 | 0.046749 | 7 | EF8 | 0.02021 | 23 |
| MC7 | 0.046714 | 8 | OP1 | 0.017079 | 24 |
| MC2 | 0.043228 | 9 | OP3 | 0.016865 | 25 |
| EC7 | 0.038284 | 10 | EF3 | 0.016049 | 26 |
| EC5 | 0.03637 | 11 | EF5 | 0.016049 | 27 |
| EC4 | 0.034455 | 12 | OP7 | 0.016011 | 28 |
| EC6 | 0.034455 | 13 | OP6 | 0.0015798 | 29 |
| EC1 | 0.033977 | 14 | OP8 | 0.015787 | 30 |
| EC2 | 0.03302 | 15 | OP4 | 0.01473 | 31 |
| EC8 | 0.030149 | 16 | OP2 | 0.013022 | 32 |

## References

[1] Damanpour F, Magelssen C, R.M.Walker R.M., **“**Outsourcing and insourcing of organizational activities: the role of outsourcing process mechanisms**”,** Public Management Review**;** 2020, 22, pp.767-790.

[2] Pournader M, Kach A, Fahimnia B, Sarkis J., **“**Outsourcing performance quality assessment using data envelopment analytics**”,** International

Journal of Production Economics**; 2019,** 207, pp.173-182.

[3] Romero M, Sandefur J, Sandholtz W.A., **"**Outsourcing education: Experimental evidence from Liberia**",** American Economic Review **; 2020,** 110, pp.364-400.

[4] Edvardsson I.R, Óskarsson G.K, Durst S., **"**The outsourcing practice among small knowledge-intensive service firms**",** VINE Journal of Information and Knowledge Management Systems**;** 2020.

[5] Kranzbühler A.M, Kleijnen M.H, Verlegh P.W., **"**Outsourcing the pain, keeping the pleasure: effects of outsourced touchpoints in the customer journey**",** Journal of the Academy of Marketing Science**; 2019,** 47, pp.308-327.

[6] Suweero K, Moungnoi W, Charoenngam C., **"**Outsourcing decision factors of building operation and maintenance services in the commercial sector**",** Property management**; 2017,** 35, pp.254-274.

[7] Rezaeisaray M, Ebrahimnejad S, Khalili-Damghani K., **"**A novel hybrid MCDM approach for outsourcing supplier selection: A case study in pipe and fittings manufacturing**",** Journal of Modelling in Management**; 2016,** 11, pp. 536-559.

[8] Van Kien P, Moslehpour M., **"**Multiple Criteria Model Study of Outsourcing Service Countries in the East and Southeast Asia**",** International Journal of Supply Chain Management**; 2017,** 6, pp.63-70.

[9] Kaur H, Singh S. P, Majumdar A., **"**Modelling joint outsourcing and offshoring decision**",** International Journal of Production Research**; 2019,** 57, pp.4278-4309.

[10] Erdoğan M, Kaya I., **"**Selection of the best outsourcing firm for WEEE under hesitant fuzzy environment**",** Journal of Intelligent & Fuzzy Systems**; 2018,** 35, pp.295-3306.

[11] Yadav G, Mangla S.K, Luthra S, Jakhar S., **"**Hybrid BWM-ELECTRE-based decision framework for effective offshore outsourcing adoption: a case study**",** International Journal of Production Research**; 2018,** 56, pp.6259-6278.

[12] Yadav S, Garg D, Luthra S., **"**Selection of third-party logistics services for internet of things-based agriculture supply chain management**",** International Journal of Logistics Systems and Management**; 2020,** 35, pp.204-230.

[13] Kahraman C, Oztaysi B, Cevik Onar S., **"**Single & interval-valued neutrosophic AHP methods: Performance analysis of outsourcing law firms**",** Journal of Intelligent & Fuzzy Systems**; 2020,** 38, pp.749-759.

[14] Barak S, Javanmard S., **"**Outsourcing modelling using a novel interval-valued fuzzy quantitative strategic planning matrix (QSPM) and multiple criteria decision-making (MCDMs) **",** International journal of production economics**; 2020,** 222, pp.107494.

[15] Ji P, Zhang H.y, Wang J.q., **"**Selecting an outsourcing provider based on the combined MABAC–ELECTRE method using single-valued neutrosophic linguistic sets**",** Computers & Industrial Engineering**; 2018,** 120, pp.429-441.

[16] Blair G, Woodcock H, Pagano R., **"**To Outsource or Not to Outsource: Resource Decision-Making in the Project Management Environment. Journal of Advanced Research in Alternative Energy**",** Environment and Ecology**; 2022,** 9(3&4), 10-20.

[17] Kiani M, Bagheri M, Ebrahimi A, Alimohammadlou M., **"**A model for prioritizing outsourceable activities in universities through an integrated fuzzy-MCDM method**",** International Journal of Construction Management**; 2022,** 22(5), 784-800.

[18] Boakai S, Samanlioglu F., **"**An MCDM approach to third party logistics provider selection**",** International Journal of Logistics Systems and Management**; 2023,** 44(3), 283-299.

[19] Igodo A, Shamsuzzoha A, Ndzibah E, Shamsuzzaman M., **"**Optimal maintenance for a waste-to-energy plant using DEMATEL: a case study**",** Clean Technologies and Environmental Policy**; 2023,** 1-29.

[20] Rezaei J., **"**Best-worst multi-criteria decision-making method: Some properties and a linear model**",** Omega**; 2016,** 64, pp.126-130.

[21] M. Mohammadi, J. Rezaei, **"**Bayesian best-worst method: A probabilistic group decision making model**",** Omega**; 2020,** 96, pp.102075.

[22] Ataei Y, Mahmoudi A, Feylizadeh M. ., Li D. F., **"**Ordinal priority approach (OPA) in multiple attribute decision-making**",** Applied Soft Computing**; 2020,** 86, pp.105893.