

Selection of Operation and Maintenance Strategic Partner Using AHP-VIKOR Model

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Abstract—In order to increase CFSPP (Coal Fired Steam Power Plant) ABC actual EAF (Effective Availability Factor) from 76% in 2019 to designed EAF 85% by taking into consideration of investment funding hardship, PT.ABC initiate to select O&M (Operation and Maintenance) Strategic Partner, but it is not an easy decision and is associated with complexity. The purpose of this paper is to propose multi criteria decision making (MCDM) approach to effectively select the best partner out of 5 pre-selected partner candidates. The approach using AHP to calculate criteria weights, then VIKOR to get the final ranking result. The criteria and sub criteria define from experts' discussion and literature review. Weights of 3 main criteria namely partner, collaboration and performance-oriented criteria are 0.113, 0.446 and 0.441. Alternative A1 is the first rank. There are 11 sub-criteria, with 3 biggest weights: 0.225 for project expectation, 0.162 for trust and 0.119 for technological capability. Project expectation and technological capability are from performance-oriented criteria while trust is part of collaboration-oriented criteria. This study can be useful for researchers to better understand of partner selection process and MCDM approach in theoretically, as well to companies in designing better partner selection system.

Keywords—Decision Making, O&M Strategic Partner Selection, AHP-VIKOR.

I. INTRODUCTION

COAL Fired Steam Power Plant (CFSPP) of "ABC" 2 x 315 MW in initial design had operational performance: Availability (EAF: Equivalent Availability Factor) minimum 85% dan Efficiency (NPHR: Nett Plant Heat Rate) of commissioning (HHV: High Heating Value) maximum 2360 kCal /kWh. In Indonesia EAF function is not only define how good or how bad the power plant performance is but also contribute to power plant's revenue. EAF is Equivalent Availability Factor, which shows the amount of power plant's availability costs to produce electricity (power plant's readiness or availability is calculated both in standby and in operation), the performance's derating should be considered too when you are calculating EAF. NPHR is Nett Plant Heat Rate, shows how efficient the process of combustion of a power plant's system in consuming coal (fossil fuel). The lower NPHR, the less heat loss that occurs, thus a power plant's system is said to be more efficient, especially in its fuel usage.

In figure 1 we see that CFSPP ABC 2 x 315 MW had never achieved its designed EAF and NPHR, the closest performance to its designed performance is in year 2015, even the NPHR reached worse than 2360 kCal/kWh. The latest performance in year 2019 achieved EAF 76% and NPHR 2892 kCal/kWh. There is an urgency to improve CFSPP ABC's operational performance. However, by taking into account the policy of Holding Company which had issued

global bonds and local bonds by giving its own and its all subsidiaries assets as collateral, making the subsidiaries of Holding Company, in this case PT XYZ could not find any investment funding sources for performance improvement cost, either banks or other financial institutions and expect investment funding from Holding Company as a shareholder is certainly difficult because it is considered to be a burden on the cash flow of Holding Company, that's why partners are needed here to be able to execute performance improvement project while funding it too at the same time.

CFSPP ABC's experts had already done initial partner selection process by using Passed/Failed Qualification as follows:

1. Having experience in running and managing China's coal-fired power plant for more than 8 years with a minimum capacity of 2 x 300 MW and an annual EAF of 88%. The experience of managing the Chinese Coal Power Plant shall include : (a) Operation and Maintenance; (b) Refurbishment and Rehabilitation; (c) Provision of strategic and non-strategic spare parts; (d) Provision of generating personnel.
2. Having competent personnel in accordance with their fields to achieve O&M (Operation and Maintenance) excellence, as evidenced by the certification of personnel in the personal biodata of personnel and shall be ready to be mobilized within a period of 1 month.
3. Had performed a similar refurbishment and rehabilitation program with a minimum program value of USD 50,000,000.
4. Have a healthy financial condition with a D&B Rating of 5A2.
5. Have a direct connection to parts suppliers in China as evidenced by the cooperation document or supporting letter.
6. Obtain funding support from banks / capital owners as evidenced banks or capital sources's supporting letter.
7. Having a good reputation, not subjected to sanctions in the red and blacklist categories within the HOLDING COMPANY Group.

Ineffective partnership can lead to the loss of core competencies and capabilities, exposure to the unexpected risks and even business failure [7], that is why the partner selection process is complicated. There are 5 (five) alternatives (A1, A2, A3, A4 and A5) that been chosen as pre-selected partner candidates, but choosing the best partner out of that 5 candidates is not an easy task. One of the complexity illustrations from the task is the tradeoff between company's financial health condition vice versa technical capability,

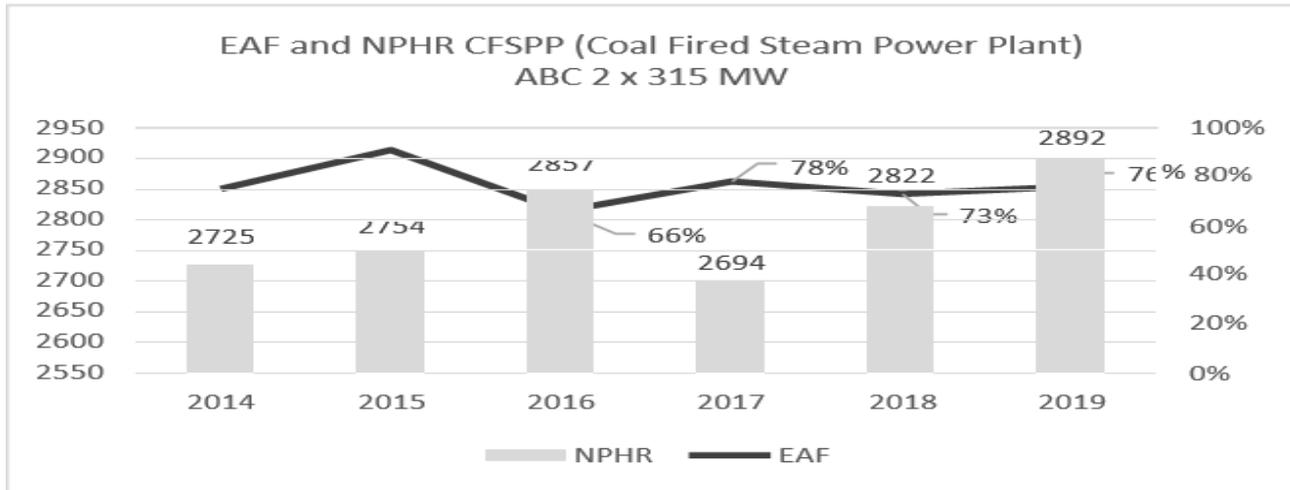


Figure 1. CFSP ABC 2 x 315 MW Operational Performance 2014-2019.

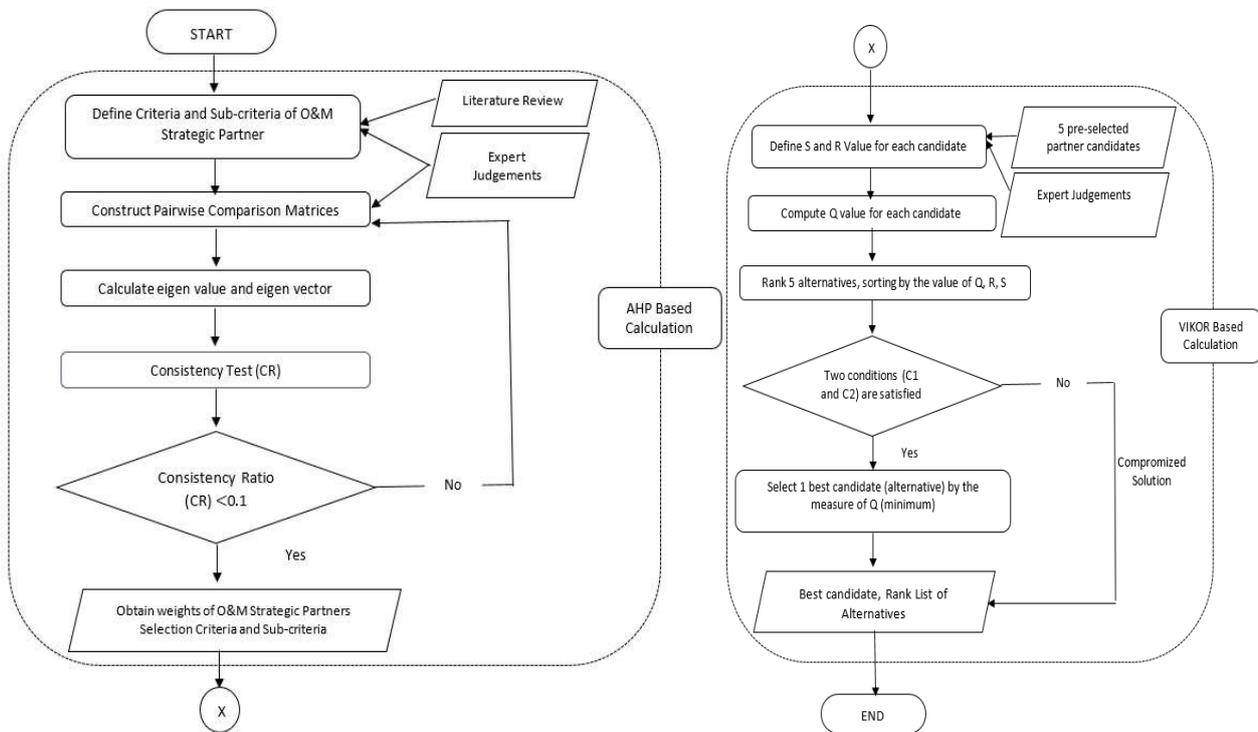


Figure 2. Research Flow Chart (a) AHP Based Calculation (b) VIKOR Based Calculation.

which one is less or more important over the other is hard to be defined. The reason is, when a candidate has a good financial capabilities but do not have the technical capability to execute project, then obviously that the project will not achieve its Service Level Agreement (SLA) targets, however this also contradicts to financial problems which will make the project's execution progress stagnant due to project financing difficulties. Thus, determining which candidate will be the best partner is even harder when there are many candidates, in this case there are 5 alternatives that seem to fulfill both criteria and at a glance that looks the same.

Analytical models for partner evaluation range from simple weighted scoring models to complex mathematical programming approaches. The most common approaches and methods for partner selection are AHP [5] and Analytic Network Process (ANP) [19], Cluster Analysis [10], goal programming [29] and multi-objective programming [27].

Considering that complexity then the researcher proposes to solve O&M Strategic Partner selection problem by using multi- criteria decision making (MCDM) framework. It is a powerful tool that is commonly used for such problems. AHP (Analytic Hierarchy Process) method is well used to weight criteria, but not in ranking the best alternative choices [24]. In ranking the best alternative choices using the VIKOR (*Višekriterijumsko KOmpromisno Rangiranje* in Serbian or Multicriteria Compromise Ranking in English Language) method proven to provide appropriate results, but in giving the weighting criteria are still lacking [20]. Therefore the AHP method and the VIKOR method are very suitable to be applied together in this study because the AHP method and the VIKOR method each have advantages and disadvantages that complement each other, can be refined by using the AHP method and the VIKOR method produces a better ranking compared to using of a single method only, since the process

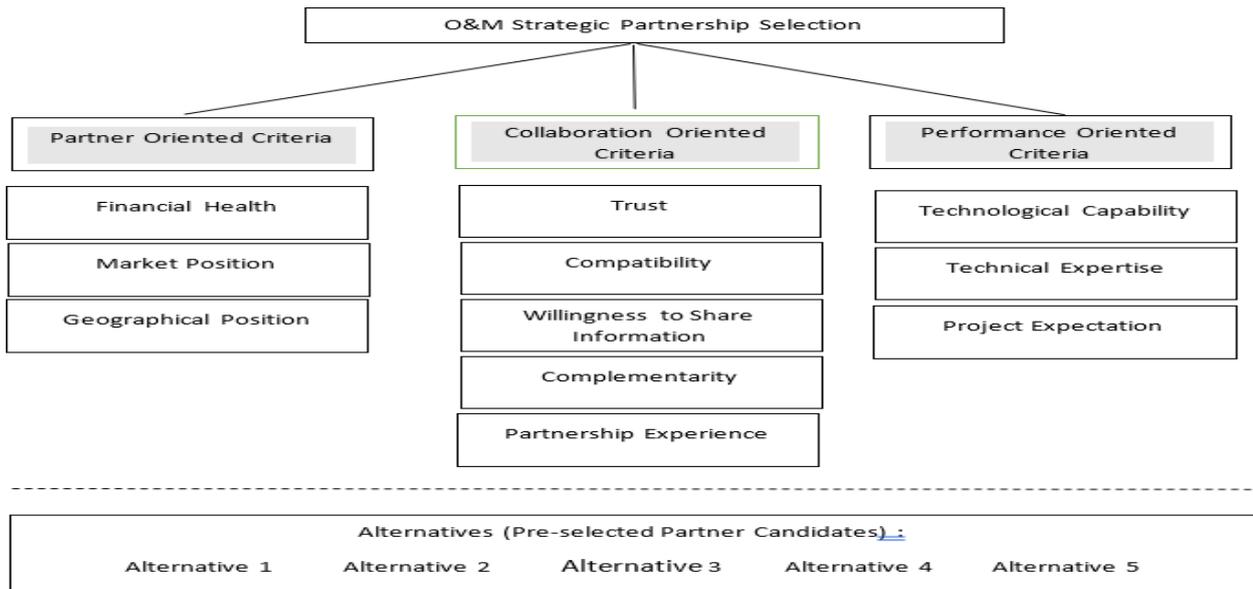


Figure 3. Criteria and Sub-criteria Structure of O&M Strategic Partner Selection.

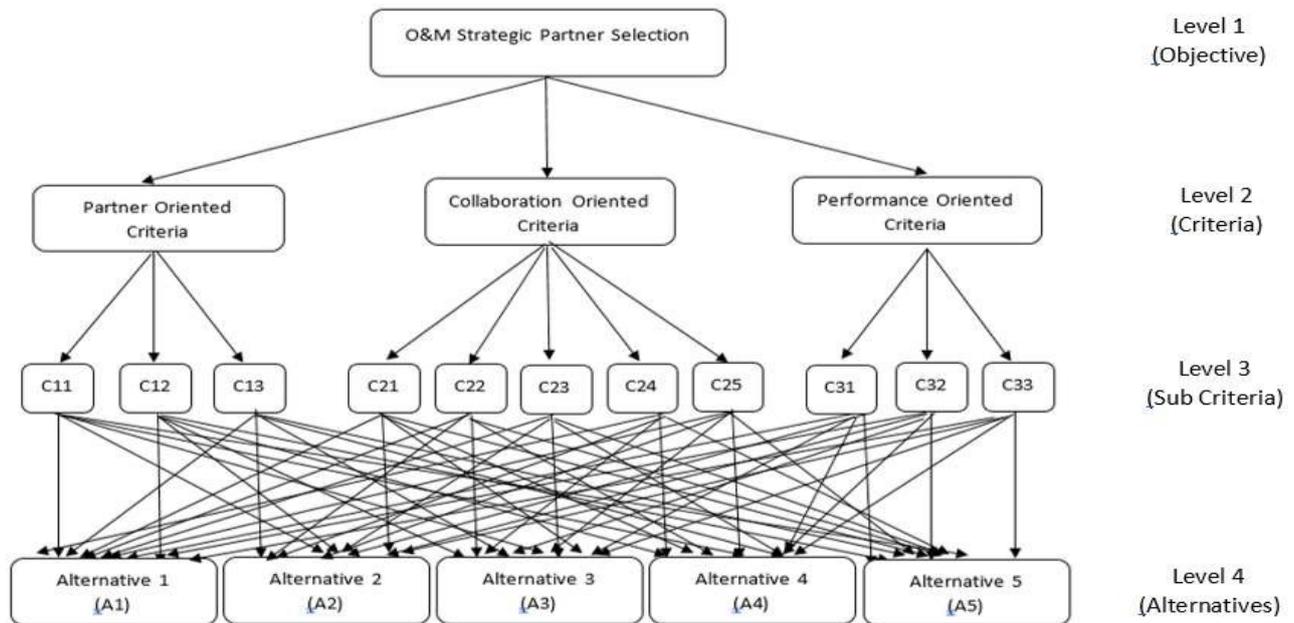


Figure 4. AHP Hierarchy Structure.

of weighting criteria using the AHP method and the VIKOR method are used in alternatives ranking [20].

II. METHOD

A. Research Flow Chart

This research using 2 (two) tools: AHP (Analytical Hierarchy Process) and VIKOR. The first step is criteria weights determination in O&M Strategic Partner selection (AHP based calculation), the second step is choosing the best alternative out of 5 alternatives by ranking (VIKOR based calculation), the flowcharts can be defined as figure 2.

In fig 2 (a), AHP based calculation process is expected to get the weight of each criterion and each sub-criterion. Initially by using literature review and expert opinions, researcher determine the criteria that are relevant and must be present in the evaluation of O&M strategic partner

candidates. Next the expert will choose the importance of each of the two criteria that are compared in the questionnaire. After the questionnaire is recapitulated, a paired matrix can be made, and the eigenvalue and eigenvector are determined. Later, Consistency Test can be done, if the value of the consistency ratio (CR) is more than 10% or 0.1 then the expert judgement on the questionnaire must be improved. But if the consistency ratio (CR) is less than or equal to 10% or 0.1 then the calculation results can be declared correct. If the CR value is met, then the weight of each criterion and sub-criteria will be obtained.

In fig 2 (b), VIKOR-based calculations, by using criteria and sub-criteria weights obtained from the AHP based calculation process and VIKOR questionnaire assessments by experts, the S (Utility Measures) and R (Regret Measures) can be calculated for each alternative candidate. Later the Q value (VIKOR index) can be calculated. The smaller the

Table 1.
Criteria and Sub-criteria Priority

Main Criteria	Criteria Priority	Sub Criteria	Sub-criteria Overall Priority
Partner Oriented Criteria	0.113	C11 Financial Health	0.075
		C12 Market Position	0.021
		C13 Geo Position	0.017
Collaboration Oriented Criteria	0.446	C21 Trust	0.162
		C22 Compatibility	0.041
		C23 Willing to share	0.049
		C24 Complementarity	0.095
		C25 Partnership Exp	0.099
Performance Oriented Criteria	0.441	C31 Techno Capability	0.119
		C32 Technical Expertise	0.096
		C33 Project Expectation	0.225

Table 2.
Alternatives Ranking using VIKOR

Alternative	Qi (v=0)	Qi	Qi	Qi	Qi	Ranking
		(v=0.25)	(v=0.5)	(v=0.75)	(v=1.00)	
A1	0.000	0.000	0.000	0.000	0.000	1
A2	0.318	0.354	0.391	0.427	0.463	2
A3	0.334	0.395	0.456	0.516	0.577	3
A4	0.678	0.659	0.639	0.620	0.600	4
A5	1.000	1.000	1.000	1.000	1.000	5

Table 3.
Alternatives Ranking using Promethee

Alternative	Leaving Flow	Entering Flow	Nett Flow	Ranking
A1	0.561	0.025	0.535	1
A2	0.198	0.195	0.002	2
A3	0.147	0.230	-0.083	3
A4	0.165	0.316	-0.151	4
A5	0.118	0.421	-0.304	5

VIKOR index value (Q_i), the better the alternative solution. After Q_i has been calculated, there will be 3 types of ranking namely s_i , R_i , Q_i . The compromise solution can be seen from the ranking of Q_i . Ranking is determined from the lowest value with a compromise solution as the ideal solution seen from ranking Q_i at the lowest value. Because the value of s_i is the solution measured from the farthest point of the ideal solution, whereas the value of R_i is the solution measured from the nearest point of the ideal solution. A compromise solution is determined from the alternative that has the best ranking using the minimum VIKOR index (the lowest Q_i).

B. Criteria Determination

Five (5) experts, that has minimum 5 (five) years working experience in Coal Fired Steam Power Plant that manage and eligible for cross department responsibilities were choosen, they are:

1. Operation Manager
2. Maintenance Manager
3. Engineering Manager
4. Procurement Manager
5. Operation Planning and Controlling Supervisor

These experts were the persons who choosed the five (5) alternatives by using Passed/Failed Qualification, later these experts and researcher would also define criteria and sub-criteria that shall be used in AHP-VIKOR procedure in fig 2. Researcher and experts consider using and modify some

criteria and sub-criteria from 13 sub-criteria to 11 sub-criteria [6], to later be weighted by using AHP Procedure (see fig 2 (a)) and rank the alternatives to choose the best partner by using VIKOR (see fig 2(b)). Here is the structure of the criteria and sub-criteria that had been defined: Figure 3.

The explanation of each criteria and sub-criteria are :

1) *Partner Oriented Criteria (C1) describes the potential and specific business activities done by the firm, independent to collaborative interactions, consists of:*

1. Financial Health (C11): Financial Health will directly affect firm’s business activities, before establishing partnership, it is important to carefully investigate partner’s financial status. The documents needed are: D&B Rating, Audited Financial Report to investigate DER (Debt to Equity Ratio) and another financial ratios needed.
2. Market Position (C12): Given the project type, what kind of company had been working together with the firm and market share the firm has in the market. The documents needed are: Project Portofolio, Market Share, Type of company that had been partnered with the firm.
3. Geographical Position (C13): Factor such as the diference of culture, tax regulation and communication and coordination problem diference due to specific location or distance. The documents needed: Domicile Letter, Branches Location and Countries where the firm expanding or running its business.

2) *Collaboration Oriented Criteria (C2) describes the interactions occur between the partnership members in doing the collaborative works/projects, consists of:*

1. Trust (C21): Mutual trust and commitment that the firm, perform well, doesn't have any hidden agenda and want a long-term partnership. The documents needed: Integrity Pact, Bank Guarantee, Bank Reference, Satisfaction Letter from previous client or partner and doesn't involve in any crimes or frauds.
2. Compatibility (C22): Cultural, Managerial, IT and communication between partnership member that will support collaborative works/projects. Documents needed: organization structure, cultural aspects like core value, IT system and language that been used in business (some China companies don't use english in their project documents)
3. Willingness to share info (C23): Transparency and share an important information regarding to projects. Documents needed: Non-Disclosure Agreement for information sharing, project planning document, quotation price component transparency.
4. Complementarity (C24): a high similarity of capabilities and resources having by partnership members will make partnership redundant and didn't give any added value, complementarity of capabilities and resources needed in a valuable partnership. Documents needed: Project portfolio, scope of works that firm had already done, any technologies or expertises that differ and enrich each partnership member.
5. Partnership Experience (C25): a previous partnership experience with the firm may help us to judge better about the firm accountability. Documents needed: Previous project contract to HOLDING COMPANY Group and Satisfaction Letter from HOLDING COMPANY Group.

3) *Performance Oriented Criteria (C3) describes the firm's capability in executing the works or projects while collaborating, consists of:*

1. Technological Capability (C31): Keeping up to become innovative and technological updated. Documents needed: Products and/or services portfolio, software and/or hardware been used by the firm.
2. Technical Expertise (C32): The ability to perform tasks as needed by the project requirements. Documents needed: Personnel Certificates and Satisfaction Letter.
3. Project Expectation (C33): Expected outcomes from collaborative work/project, regarding to fulfillment of Service Level Agreement in the contract. Documents needed: Firm's Previous contract's Service Level Agreement, projects planning document.

This criterion shall be prioritized and used to assess 5 (five) alternatives and rank them to choose the best partner. The relationship of each criterion and sub-criteria and alternatives are shown in fig 4.

III. RESULT AND DISCUSSION

As discussed in Section 2.1 and Figure 4, the O&M Strategic Partner Selection model contains three criteria with 11 sub- criteria that are all confirmed by CFSPP ABC 2 x 315

MW experts. There are five (5) possible partners (A1, A2, A3, A4 and A5) determined by experts that passed the Passed/Failed Qualification. As a result, the decision problem consist of four levels: Level 1 is the objective of the problem is situated. In the Level 2 the criteria are listed, in the Level 3 the sub-criteria are listed. The Level 4 belongs to the alternatives.

A. AHP Based Calculation

It is not possible to to assume that all the identified evaluation factors are of equal importance. AHP is used here to determine the decision criteria weights [28]. First step AHP method is the pairwise comparisons of the criteria and the sub-criteria by using experts' judgement and evaluation in order to obtain their weights. After constituting pairwise comparison matrices, priority scores of main criteria and sub-criteria are specified by using relative weights calculations. The normalized priority weights among the criteria and sub-criteria have been depicted in Table 1. From the Sub-criteria overall priority column, we may conclude that the Project Expectation (0.225), Trust (0.162), Technological Capability (0.119), Partneship Experience (0.099), Technical Exerise (0.096) and Complementarity (0.095) are the biggest six weights compared to other sub-criteria. While Geographical Position (0.017) and Market Position (0.021) are two the least weights sub-criteria.

B. VIKOR Based Calculation

At this step, the VIKOR method is applied in obtaining ranking list of alternatives. S, R and Q values of the 5 (five) alternatives are computed. In the calculation, v is assumed to be 0.5. This means that the compromise solution can be selected with consensus. The alternatives are ranked by sorting S,R and Q values in an increasing order in the VIKOR method. As we see in Table 2 the best ranked alternative is A1. Note that the value of the weight v has a central role in the ranking of alternatives. The value of v representing the weight of utility measure, $1-v$ representing the weight of regret measure. When the experts want to exercise different scenario, v can be changed accordingly. The results of analysis are presented in Table 2.

C. Comparative Validation Using PROMETHEE II

PROMETHEE (Preference Ranking Organization Method for Enrichment Evaluations) is developed in 1982 [2] and further extended in 1985 [3] and 1994 [4]. It belongs to the methods of partial aggregation, or also called outranking methods. Three main PROMETHEE tools can be used to analyse the evaluation problem: (1) PROMETHEE I partial ranking, (2) PROMETHEE II complete ranking and (3) the GAIA plane. In PROMETHEE I, the partial ranking is obtained from the positive and negative outranking flows (see Formulas 3 and 4). In this respect, alternative (a) is preferred to alternative (b) if it has a high positive flow and a low negative flow. In some cases, the ranking of alternatives may be incomplete as PROMETHEE I allows indifference (both positive and negative flows are equal) and incomparability (alternative (a) scores high on a set of criteria on which (b) is weak and vice versa) situations. PROMETHEE II provides a complete ranking of the alternatives from the best to the worst

one, which is based on the net preference flow (see Formula 5). The Geometrical Analysis for Interactive Aid (GAIA) plane provides a graphical representation in which the alternatives and their contributions to the criteria are displayed. Additionally, a decision stick can be used to further investigate the sensitivity of the results in function of weight changes [3].

By using the same criteria and sub-criteria weights obtain from AHP method we may proceed to PROMETHEE. Firstly, by using complete ranking (PROMETHEE II) thus using Net Flow to rank alternatives, the bigger Net Flow then the better rank. In the Table 3 we may conclude that A1 is still the best alternative followed by A2, A3, A4 and A5. AHP-PROMETHEE II result as comparative validation gave the same ranking as AHP-VIKOR, thus means that AHP-VIKOR method is reliable to be used in this research.

IV. CONCLUSION

The selection of O&M Strategic Partner for CFSPP ABC 2 x 315 MW performance improvement is not an easy task and is associated with complexity. Multiple influencing factors should be take into account in the partner selection process. Based on experts' opinions and literature review, there are 11 sub-criteria that are grouped into 3 criteria, there are :(1)Partner Oriented Criteria consists of : Financial Health, Market Position and Geographical Position; (2)Collaboration Oriented Criteria consists of : Trust, Compatibility, Willingness to share information, Complementarity and Partnership Experience; (3)Performance Oriented Criteria consists of : Technological Capability, Technical Expertise, Project Expectation Partner Oriented Criteria consider the individual attributes of the O&M Strategic Partner candidates, Collaboration Oriented Criteria consider the interaction that may occur between the respective partner and CFSPP ABC 2 x 315 MW when they are working together and finally Performance Oriented Criteria consider the capability of each partner candidates in fulfill the project's Service Level Agreement in the collaboration contract.

The biggest weight criteria is Collaboration Oriented Criteria (0.446), then Performance Oriented Criteria (0.441) and lastly Partner Oriented Criteria (0.113) while the top six biggest weights for sub-criteria are Project Expectation (0.225), Trust (0.162), Technological Capability (0.119), Partnership Experience (0.099), Technical Expertise (0.096) and Complementarity (0.095) are the biggest six weights compared to other sub-criteria. While Geographical Position (0.017) and Market Position (0.021) are two the least weights sub-criteria. Alternative 1 chosen as the best alternative both by using VIKOR and PROMETHEE as comparative validation. According to the managers, the suggested evaluation framework is clear, and the decision model is helpful to make decision. This indicates that the case study helped to validate that the AHP-VIKOR approach is an effective and efficient decision-making tool for partner selection process.

In this research, the interactions among and between evaluation criteria are not considered. One of the aspects that need to be study is the dependence of the criteria and the interaction between the criteria. In general, multi criteria problems adhere to uncertain environment of human subjectivity and imprecise evaluation data. In order to model this kind of uncertainty fuzzy logic can be applied.

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