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RESEARCH ARTICLE

VENDOR SELECTION FOR LONG-TERM PARTNERSHIP -EMPLOYING CRITIC AND TOPSIS METHODS

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Abstract

Organizations are under constant pressure to adapt comprehensive, systematic and formal quantitative assessment methods for vendor selection focusing on long term relationship potential and enhancing the delivery performance of ongoing projects. As government decisions for future project assignments is dependent on the performance of the ongoing projects.However, the process of vendor selection within the supply chains, is left to the uncertain and imprecise judgements of the decision makers & top management. This limits the usage of comprehensive, systematic and formal quantitative assessment methods for identifying a potential vendor for long term collaboration. Therefore, this article aims at understanding the important criterion/attributes for supplier selection using an Industrial case and providing a methodology for identifying a potential vendor for long term partnership.

Introduction:-

According to [1], supplier selection problem is multi-criterion in nature and is of strategic importance to the firms. Further the authors stated that, such decisions are complex in nature and thus require management science techniques for resolution. In addition, the authors also expressed that, the objective of supplier selection is to identify potential suppliers through broad comparison of common set of criteria and measures.

Similarly [2], urged to use systematic and transparent approaches for supplier selection and recommended the usage of decision models and techniques within Operations Research such as multi-criteria decision aids, problem structuring approaches, mathematical programming and data mining techniques for supplier selection. In addition [3], conducted an in-depth literature review on Multi-Criteria Decision-Making methods and identified the usage of Analytical Hierarchic Process (AHP), Analytical Network Process (ANP), Data Envelopment Analysis (DEA), Grey Relational Analysis (GRA), Artificial Neural Networks (ANN), Goal Programming (GP), Linear Programming (LP), Multi-Objective Programming (MOP), Simple-Multi-Attribute Rating Technique (SMART), Case Based Reasoning (CBR), Genetic Algorithms (GA), Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS)& Hybrid Methods for Supplier Selection Problems.

However, research focusing on combined usage of Criteria Importance through Intercriteria Correlation (CRITIC) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is limited to Sustainable Supply Chain Risk Management Evaluation [4], Financial Performance Assessment [5], Multi-Response Optimization [6] and Site Selection [7] etc.

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This research concentrates on employing CRITIC and TOPSIS together for identifying a potential vendor for long term partnership and collaboration using the data on key attributes related to Battery Suppliers that serve a firm (XYZ) involved in Oil and Gas Offshore Projects.

The next sections within this report, would elaborate on defining the Aim & Objectives for addressing the identified problem; exploring the literature on key performance criterion for supplier selection; detailing specific procedures and techniques that are used for identifying a potential vendor; pursuing data analysis employing CRITIC and TOPSIS together; stating the results and conclusions based on the data analysis pursued and finally listing the limitations of the study and ethical norms followed for pursuing the study

Research Aim:
The study is aimed at selecting a potential vendor for long term collaboration and partnership.

Research Objective:-

The study is pursued to fulfil an objective of "Using an Industrial case to demonstrate the application of comprehensive, systematic and formal quantitative methods for vendor selection" and to employ "Multi-Criteria Decision-Making Methods (MCDM) such as CRTIC & TOPSIS for selecting a potential vendor for long term partnership, collaborative growth and development".

Literature Review:-

The section aims to examine the literature related to Supplier Selection Criterion, Multi-Criteria Decision-Making Methods and the Importance of Batteries for Oil and Gas Offshore Applications.

Supplier Selection Criterion:
According to [8], Supplier Selection Process involves Identification, Evaluation and Final Selection of Suppliers and it is one of the critical processes- as it deploys a lot of firms resources and plays a crucial role in the success of the firms operations, hence identification of critical parameters or criterion for selection is highly important for reducing purchase risks, maximizing the overall purchase value and developing long term relationships for collaborative growth. Further [9, 10 & 11], highlighted the importance of the ability of the supplier to consistently meet the "Quality"requirements for material, dimensions, design, durability, variety and also the ability of the supplier to continuously improve quality through implementation of Quality Systems for control, assessment and continuous improvement. Further [12], highlighted the importance of "Technical Expertise and Experience" as an important criterion for Supplier Selection for Technology Oriented Projects.

In addition, [10 & 12], underlined the importance of "Price Factor" for supplier selection- that includes product unit prices and additional costs for warranty, installation, delivery etc. Likewise [10, 11 & 13], emphasized on the importance of delivery times for on-time project completions and inclusion of "Delivery Factor" for supplier selection.

Multi-Criteria Decision-Making Methods:
According to [14], Multi-Criteria Decision-Making (MCDM) is one of the fastest growing problem areas across many disciplines, as it involves evaluation of set of alternatives based on a number of conflicting criterion, further the authors classified MCDM into Multiple Attribute Decision Making (MADM)- involving selection of a best alternative from a set of pre-specified alternatives and Multiple Objective Decision Making (MODM)- involving the design of multiple alternatives to optimize the multiple objectives specified by the decision maker. Likewise [15], conducted an in-depth literature review- to list out the major MCDM methods applied within the Supply Chain Domain and identified that Analytical Hierarchic Process (AHP), Analytical Network Process (ANP), Fuzzy Sets, TOPSIS and Hybrid methods were most commonly used for solving problems related to Supplier Selection, Manufacturing, Warehousing and Logistics within the supply chains.

In addition [16], stated that AHP can be applied to supplier selection problems- as itaids the decision maker to provide judgments about the relative importance of each criterion and then specify a preference for each decision alternative using each criterion in order to finally provide a prioritized ranking of the decision alternatives based on the overall preferences specified for the alternatives. Likewise [17], illustrated the usage of ANP within a

Hospitality Industry -which is a general form of AHP where dependence among alternatives and criteria are considered for pairwise comparisons in order to convene the final supplier selection.
Further [18], demonstrated the use of Fuzzy logic- that enables emulation of human reasoning for making decisions based on imprecise data. Additionally, the authors also illustrated that the method also enables calculation of a fuzzy suitability index for the efficient vendor alternatives- to help rank the fuzzy indices for best supplier alternative selection.

Likewise [19], employed TOPSIS for supplier selection where in the best alternative is selected based on the shortest geometric distance from the positive ideal solution and negative ideal solution. Similarly [20], developed a hybrid model wherein the authors -formulated criterion for the proposed model, performed AHP computations and defined a Fuzzy TOPSIS logic for evaluating and ranking of supplier alternatives.

Importance of Batteries for Oil and Gas Offshore Applications:
According to [21], Batteries are Electro Chemical Devices that store and release energy through conversion of Chemical Energy to Electricity. Further the author, defined a Primary Battery as the one that cannot be recharged and Secondary Batteries as the ones that can be recharged. In addition, the authors also projected the use of Secondary batteries as a reliable backup power source that guarantees the safe operation of critical equipment within Offshore Applications. According to the author, the Batteries can be used for multiple offshore applications -such as Process controls, UPS, Turbine Operations, Emergency Lighting, Safety Systems and Switchgear Operations.

Research Methodology:-
Supplier Specific data on "Price per AH", "Years of Experience- portraying the Technical Expertise", "Delivery Lead Times", "Transportation Charges" and "Quality Ratings" was collected for an Offshore Emergency Lighting Application with a Total Load Requirement of 18 Amps, Back up Time Requirement of 180 min and a Nominal System Voltage Requirement of 110 V. Data was collected for a total of five suppliers belonging to local and international territories. A hybrid method that combined the CRITIC and TOPSIS methods was used for selecting the best Supplier.

According to [22], the CRITIC method is used to determine the objective weights for the selection criterion based on the quantification of two fundamental notions of Multi-Criteria Decision- Making i.e., the contrast intensity and the conflicting character of the evaluation criteria. The CRITIC process starts by defining the decision matrix with 'm' feasible alternatives A_i (i=1,2, ….m) and 'n' evaluation criterion C_j (j= 1,2, …. n).

Step 1: A decision matrix with the performance values for different alternative for each of the criterion is developed.

$$X = [Xij]_{mxn} = \begin{bmatrix} X11 & \cdots & X1n \\ \vdots & \ddots & \vdots \\ Xm1 & \cdots & Xmn \end{bmatrix}$$ (i=1,2, ….m and j= 1,2, …. n) &

Xij represents the performance value of the i^{th} alternative for the j^{th} criterion.
Then Best -max (Xij)and Worst- min (Xij) performance values are evaluated for each criterion.

Step 2: The decision matrix is Normalized by evaluating Xij' for each of the Xij using

$$Xij' = \frac{\boldsymbol{Xij - min\ (Xij)}}{\boldsymbol{max(Xij) - min(Xij)}}$$

Based on the Normalized Matrix the Standard Deviation $\boldsymbol{\sigma_j}$values for each of the Criterion are calculated.

Step 3: A Symmetric matrix of nxn, with elements r_{jk}- linear correlation coefficients between vectors X_j and $X_k$is defined.

Step 4: A Measure of conflict created by criterion j, with respect to decision situation defined by the rest of the criteria is calculated using

$$\sum_{k=1}^{m}(1 - rjk)$$

Step 5: Quantity of Information in relation to each Criterion is calculated using

$$c_j = \sigma_j * \sum_{k=1}^{m}(1 - rjk)$$

Step 6: Finally, Objective weights for each Criterion are determined using

$$W_j = \frac{C_j}{\sum_{k=1}^{m} C_j}$$

The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS) is one of the classical Multi-Criteria Decision- Making Methods developed by [23]. The method identifies the best solution by calculating the shortest Geometric/ Euclidean distance from the positive ideal solution and negative ideal solution. The algorithm below (Fig 4.1), demonstrates the basic steps to be followed in order to define the preference order for the alternatives.

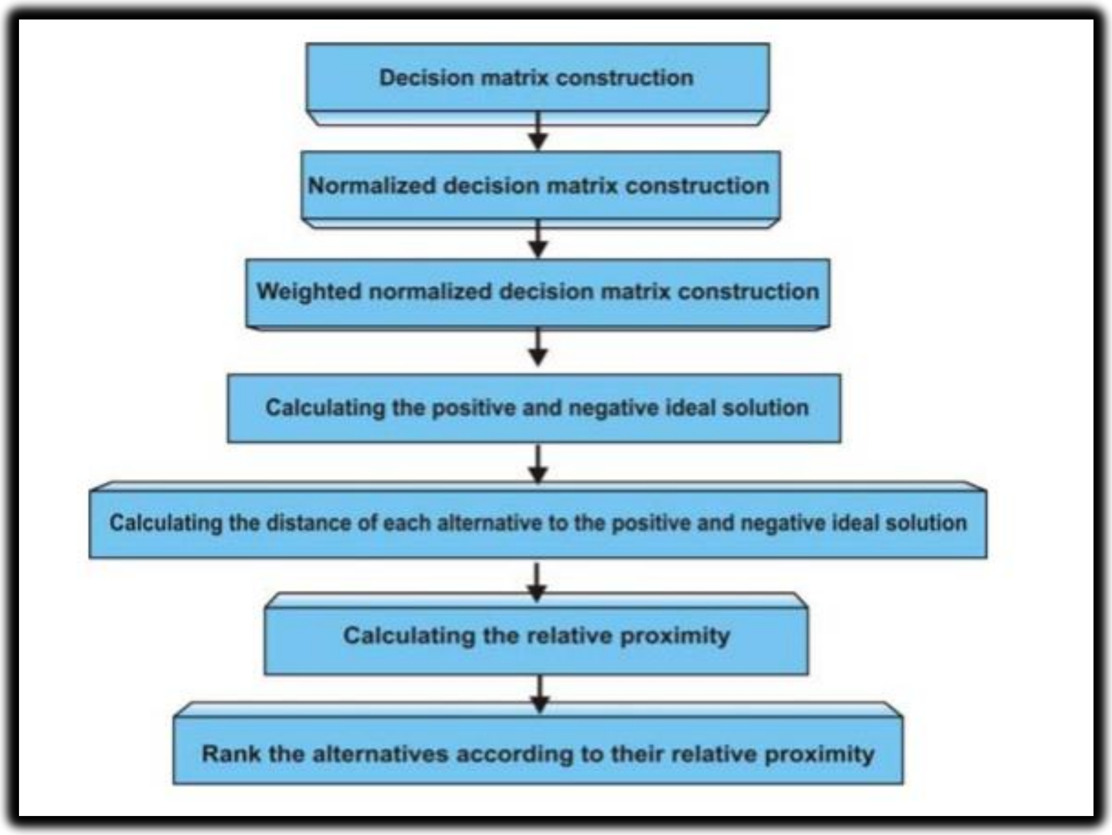

Figure 4.1:- Topsis Algorithm, Adapted fromEspinosa et.al [24, p.5].

A Hybrid method was employed for the final data analysis, wherein the objective weights defined by the CRITIC Method, were used for formulating the Weighted Matrix within the TOPSIS method.

Data Analysis:

Critic Method:

Step 1: Creation of the decision matrix with the performance values for different alternatives for each of the criterion (Table 1).

Table 1:- Decison Matrix.

Vendor Name	Price per AH (₹)	Experience - Battery Technical Expertise (Years)	Delivery Lead Times (Weeks)	Transportation Charges (% of total Battery Bank Pricing)	Quality Rating Based on Customer Feedback (Scale of 1-5)
Supplier-1	34.78	25	6	2	4
Supplier-2	33.66	14	8	2	4.5
Supplier-3	39.85	100	12	15	5
Supplier-4	41.75	19	10	10	3.5

Supplier-5	40.9	100	10	8	5
Best	33.66	100	6	2	5
Worst	41.75	14	12	15	3.5

Step 2: Defining the Normalized Decision Matrix (Table 2)

Table 2:- NormalizedDecison Matrix.

Vendor Name	Price per AH (₹)	Experience - Battery Technical Expertise (Years)	Delivery Lead Times (Weeks)	Transportation Charges (% of total Battery Bank Pricing)	Quality Rating Based on Customer Feedback (Scale of 1-5)
Supplier-1	0.862	0.128	1.000	1.000	0.333
Supplier-2	1.000	0.000	0.667	1.000	0.667
Supplier-3	0.235	1.000	0.000	0.000	1.000
Supplier-4	0.000	0.058	0.333	0.385	0.000
Supplier-5	0.105	1.000	0.333	0.538	1.000
σj	0.458	0.516	0.380	0.427	0.435

Step 3: Defining a Symmetric matrix of nxn, with elements r_{jk}- linear correlation coefficients between vectors X_j and X_k (Table 3).

Table 3:- Symmetric Matrix.

σj	0.458	0.516	0.380	0.427	0.435
	Price per AH (₹)	**Experience - Battery Technical Expertise (Years)**	**Delivery Lead Times (Weeks)**	**Transportation Charges (% of total Battery Bank Pricing)**	**Quality Rating Based on Customer Feedback (Scale of 1-5)**
Price per AH (₹)	1.000	-0.540	0.764	0.793	-0.037
Experience - Battery Technical Expertise (Years)	-0.540	1.000	-0.690	-0.670	0.789
Delivery Lead Times (Weeks)	0.764	-0.690	1.000	0.939	-0.411
Transportation Charges (% of total Battery Bank Pricing)	0.793	-0.670	0.939	1.000	-0.253
Quality Rating Based on Customer Feedback (Scale of 1-5)	-0.037	0.789	-0.411	-0.253	1.000

Step 4: Calculating the Measure of conflict created by criterion j, with respect to decision situation defined by the rest of the criteria (Table 4)

Table 4:- Measure of Conflict.

	Price per AH (₹)	Experience - Battery Technical Expertise (Years)	Delivery Lead Times (Weeks)	Transportation Charges (% of total Battery Bank Pricing)	Quality Rating Based on Customer Feedback (Scale of 1-5)	$\sum_{k=1}^{m}(1-rjk)$
Price per AH (₹)	0.000	1.540	0.236	0.207	1.037	3.020
Experience - Battery Technical Expertise (Years)	1.540	0.000	1.690	1.670	0.211	5.110
Delivery Lead Times (Weeks)	0.236	1.690	0.000	0.061	1.411	3.398
Transportation Charges (% of total Battery Bank Pricing)	0.207	1.670	0.061	0.000	1.253	3.191
Quality Rating Based on Customer Feedback (Scale of 1-5)	1.037	0.211	1.411	1.253	0.000	3.911

Step 5: Calculating the Quantity of Information in relation to each Criterion (Table 5)

Table 5:- Quantity of Information-Criterion.

	$\sum_{k=1}^{m}(1-rjk)$	σj	Cj
Price per AH (₹)	3.020	0.458	1.383
Experience - Battery Technical Expertise (Years)	5.110	0.516	2.635
Delivery Lead Times (Weeks)	3.398	0.380	1.291
Transportation Charges (% of total Battery Bank Pricing)	3.191	0.427	1.362
Quality Rating Based on Customer Feedback (Scale of 1-5)	3.911	0.435	1.700

Step 6: Finally, calculating the Objective weights for each Criterion (Table 6)

Table 6:- Objective Weights-Criterion.

	Objective Weights Wj
Price per AH (₹)	**0.165**
Experience - Battery Technical Expertise (Years)	**0.315**
Delivery Lead Times (Weeks)	**0.154**
Transportation Charges (% of total Battery Bank Pricing)	**0.163**
Quality Rating Based on Customer Feedback (Scale of 1-5)	**0.203**

TOPSIS Method:

Step 1: Creation of the decision matrix with performance values for different alternatives for each of the criterion (Table 7).

Table 7:- Decison Matrix.

Vendor Name	**Price per AH (₹)**	**Experience - Battery Technical Expertise (Years)**	**Delivery Lead Times (Weeks)**	**Transportation Charges (% of total Battery Bank Pricing)**	**Quality Rating Based on Customer Feedback (Scale of 1-5)**
Supplier-1	34.78	25	6	2	4
Supplier-2	33.66	14	8	2	4.5
Supplier-3	39.85	100	12	15	5
Supplier-4	41.75	19	10	10	3.5
Supplier-5	40.9	100	10	8	5
Best	33.66	100	6	2	5
Worst	41.75	14	12	15	3.5

Step 2: Defining the Normalized Decision Matrix- through Vector Normalization using (Table 8).

$$Xij' = \frac{Xij}{\sqrt[2]{\sum_{j=1}^{n} Xij^2}}$$

Table 8:- NormalizedDecison Matrix.

Vendor Name	**Price per AH (₹)**	**Experience - Battery Technical Expertise (Years)**	**Delivery Lead Times (Weeks)**	**Transportation Charges (% of total Battery Bank Pricing)**	**Quality Rating Based on Customer Feedback (Scale of 1-5)**
Supplier-1	0.406	0.172	0.285	0.100	0.403
Supplier-2	0.393	0.096	0.380	0.100	0.453
Supplier-3	0.465	0.687	0.569	0.753	0.504
Supplier-4	0.487	0.131	0.475	0.502	0.353
Supplier-5	0.477	0.687	0.475	0.402	0.504

Step 3: Defining the Weighted Normalized Decision Matrix- using the Weights from the CRITIC Method (Table 9 and 10)

Table 9:- Criterion Weights from the CRITIC Method.

	Price per AH (₹)	**Experience - Battery Technical Expertise (Years)**	**Delivery Lead Times (Weeks)**	**Transportation Charges (% of total Battery Bank Pricing)**	**Quality Rating Based on Customer Feedback (Scale of 1-5)**
Weights for Criteria	0.165	0.315	0.154	0.163	0.203

Table 10:- Weighted Decision Matrix.

Vendor Name	Price per AH (₹)	Experience - Battery Technical Expertise (Years)	Delivery Lead Times (Weeks)	Transportation Charges (% of total Battery Bank Pricing)	Quality Rating Based on Customer Feedback (Scale of 1-5)
Supplier-1	0.067	0.054	0.044	0.016	0.082
Supplier-2	0.065	0.030	0.059	0.016	0.092
Supplier-3	0.077	0.216	0.088	0.122	0.102
Supplier-4	0.080	0.041	0.073	0.082	0.072
Supplier-5	0.079	0.216	0.073	0.065	0.102
Ideal Best Vj+	0.065	0.216	0.044	0.016	0.102
Ideal Worst Vj-	0.080	0.030	0.088	0.122	0.072

Step 4:- Calculating the Euclidean Distance from the Ideal Best and the Ideal Worst (Table 11).

$S_i^+ = \left[\sqrt[2]{\sum_{j=1}^{m}(Vij - \mathbf{Vj+})\text{^}\mathbf{2}}\right]$ and $S_i^- = \left[\sqrt[2]{\sum_{j=1}^{m}(Vij - \mathbf{Vj-})\text{^}\mathbf{2}}\right]$

Table 11: Euclidean Distances

Vendor Name	S_i^+	S_i^-
Supplier-1	0.163	0.119
Supplier-2	0.187	0.113
Supplier-3	0.115	0.189
Supplier-4	0.192	0.045
Supplier-5	0.059	0.197

Step 5:- Finally, Calculate the Performance Score Matrix (Table 12).

$P_i = \frac{(Si-)}{(Si+)+(Si-)}$

Table 12:- Performance Score Matrix.

Vendor Name	P_i	Ranking
Supplier-1	**0.420**	**3**
Supplier-2	**0.377**	**4**
Supplier-3	**0.620**	**2**
Supplier-4	**0.189**	**5**
Supplier-5	**0.771**	**1**

Results and Conclusion: -

Based on the analysis using the Hybrid Method for identifying a potential supplier for long term partnership using Supplier Specific data on "Price per AH", "Years of Experience- portraying the Technical Expertise", "Delivery Lead Times", "Transportation Charges" and "Quality Ratings" collected for an Offshore Emergency Lighting Application with a Total Load Requirement of 18 Amps, Back up Time Requirement of 180 min and a Nominal System Voltage Requirement of 110 V.

The Supplier-5 received the highest performance score based on the TOPSIS method- which can be attributed to the highest experience and highest quality rating values for the supplier, as these criteria received the highest objective weights based on the CRITIC Method. Therefore, it can be concluded that a combination of CRITIC and TOPSIS methods, can provide an ideal solution for Multi-Criterion Decision-Making problems.

Limitations:

The focus of the study is limited to a firm (XYZ) involved in Oil and Gas Offshore Projects that works in collaboration with a Battery Supplier, however the methods used can be adopted to other firms in other geographical locations by feeding the data about the relevant suppliers.

The focus of the data analysis was limited the use of Batteries for one of the offshore applications (Emergency Lighting), however the analysis can be extended to other offshore applications such as Process controls, UPS, Turbine Operations, Safety Systems and Switchgear Operations. Finally, the data collected is assumed to be reliable, as it is acquired from the reports provided by the firm (XYZ) involved in Oil and Gas Offshore Projects.

Ethics:
As the study employs real-time data for analysis, the expectations of the study were clearly communicated to the Industry fraternity providing the data for analysis. The pertinent data management and storage protocols were followed to ensure the integrity of the data provided.

The rights, privacy and safety of people and firms involved either directly or indirectly were ensured and no individual was forced to participate, and the participation was voluntary convened through the gatekeepers within the organizations involved [25].

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