ISSN 1816-6075 (Print), 1818-0523 (Online)
Journal of System and Management Sciences
Vol. 14 (2024) No. 10, pp. 364-382
DOI:10.33168/JSMS.2024.1021

Determining Key Influencers in Oil Service Supplier Selection: A Multi-Criteria Decision-Making Approach

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Abstract. The oil service industry requires specialized supplier selection approaches that account for its operational complexity. This research uses a tailored framework leveraging a modified TOPSIS method and expert surveys to determine influential criteria across diverse market scenarios. Findings revealed supplier document completeness, technical ability, pricing competitiveness and health safety compliance as consistent top determinants. However, depending on conditions, risk mitigation, reputation, and local content development remain relevant. The multi-factor model provides a nuanced protocol for procuring suppliers most aligned to the industry's needs. This study contributes by addressing a significant knowledge gap through a methodology catering to the oil sector's unique supplier selection requirements related to environmental management and occupational hazards.

Keywords: Service industry, Supply chain, Supplier selection, Supplier Performance, TOPSIS

1. Introduction

The oil and gas industry plays a crucial role in numerous industries and the overall process of industrialization (Wang et al. 2018). (Wang et al. 2018). The oil service industry is pivotal in the global energy sector, facilitating oil extraction, refinement, and distribution (Khatun et al., 2017). With its expansive operations, the industry relies heavily on a robust supplier network to ensure smooth functioning (Fallahpour et al., 2021; Lu et al., 2019). Supplier selection and evaluation are imperative processes that directly impact the industry's efficiency, safety, and environmental compliance. In the oil and gas industry, oil corporations depend on various services provided by oilfield service companies (OGS). They provide and establish services to address various challenges in locating hydrocarbon resources, starting from the initial stage of prospecting through seismic studies, drilling and exploration, all the way to production, well maintenance, workover, and infrastructure construction. Hence, the implementation of OGS will enhance the efficacy and productivity of all activities associated with the oil and gas industry, benefiting both individual companies and the nation as a whole (Kryukov & Tokarev, 2018). Experts assert that OGS plays a vital role in the advancement and execution of numerous novel technologies and patents for hydrocarbon production (Perrons, R, 2014). Given the volatile nature of the oil and gas industry, characterized by unpredictable fluctuations in oil prices, the working conditions are demanding, hazardous, and subject to constant instability. Therefore, oil companies are unable to acquire all the advanced technological equipment and hire a large workforce of highly skilled personnel to carry out their tasks. Engaging in a collaborative partnership with OGS through the use of outsourcing will help distribute the risk associated with the underutilization of equipment and personnel and human movement.

As a cornerstone of energy production, the oil service industry operates on a grand scale, requiring an intricate web of suppliers to support its diverse needs (Kuo et al., 2021; Muazu & Tasmin, 2017). These suppliers range from human resources providers to heavy machinery rental services, each contributing to the industry's operations. The industry's reliance on a seamless supplier chain is magnified by its capital-intensive projects and environmental and social responsibilities.

Despite the industry's recognition of the significance of supplier selection and evaluation, existing methods often must be revised to address the industry's unique requirements. The conventional methods based on specific criteria and frameworks may only partially capture the intricacies of the oil service industry's supplier landscape (Wang, Nguyen, et al., 2018). As such, a research gap emerges, prompting the need for a specialised approach that aligns with the industry's distinct characteristics.

Previous studies have investigated supplier selection methodologies in various industries, such as agri-food (Banaeian et al., 2018; Siakwah, 2017), automotive (Jain et al., 2018), pharmaceutical (Sabouhi et al., 2018), and Small and Medium Enterprises (SME) (Gupta & Barua, 2017), highlighting the importance of pricing, quality, delivery, and reputation attributes. However, the oil service industry presents distinctive challenges that require a tailored approach (Akinwale et al., 2018). The supply chain in the oil and gas sector was not considered for quite a while (Tati,2020). According to Mohammad (2008), it captivated practitioners only after corporations suffered a crisis and realized that the expense came from the supply chain. The existing supplier selection models may need to fully capture the complex considerations, such as direct involvement with occupational health risks and high-cost potential business (Schramm et al., 2020).

While there is a wealth of research on supplier selection in various industries, there is a research gap in the oil services industry. Existing models need to comprehensively address the critical requirements of supplier selection and the unique challenges of this industry (Kaviani et al., 2020). This research aims to fill this gap by developing a specialised framework that incorporates the specific characteristics of the industry to ensure effective and informed supplier decisions.

The primary objective of this research is to develop a robust supplier selection and evaluation framework tailored to the intricate demands of the oil service industry. This framework will consider criteria of utmost relevance to the industry's functioning, such as direct involvement with occupational safety risks, reputation, delivery, and reliability. By achieving this objective, the study aims to enhance the efficiency and effectiveness of supplier management, ultimately contributing to improved supply chain performance.

The paper is structured as follows. Section 2 delves into related literature. Section 3 describes the methodology. Section 4 explains the results and performs the discussion. Finally, Section 5 concludes the study.

2. Literature Review

2.1.Distinctive Challenges of the Oil Service Industry

The oil service industry operates within a complex and demanding environment characterized by its critical role in the global energy sector. This industry facilitates various stages of the oil supply chain, including exploration, extraction, production, and distribution (Azzedin & Ghaleb, 2019). Unlike conventional industries, the oil service sector faces many unique challenges from its intricate operations, stringent safety standards, and global economic dependencies (Semenova & Al-Dirawi, 2022). The vast scale of operations, often spanning remote and challenging geographic locations, introduces logistical complexities that demand specialized supplier solutions. Furthermore, the industry's operations are subject to volatile market dynamics, regulatory changes, and environmental concerns, adding uncertainty layers to the supplier selection process (Kryukov & Tokarev, 2018). The gas and oil industry exhibits complex dynamics, and the oilfield service industry plays a significant role within this context. Volatility and uncertainty are prevalent in this industry. The shareholders are experiencing significant challenges due to job losses, declining stock returns, and low profit margins. Amidst the economic downturns of 2014 and 2016, a significant 36% of companies in the oilfield service sector were forced to halt their operations. The revenues experienced a substantial decline of approximately 55%, while particular sectors suffered job losses exceeding 50% (Deloitte, 2017).

The oilfield service sector companies are currently in a precarious situation that requires a careful equilibrium to ensure their ability to adjust to the volatility (Shuen, Feiler, & Teece, 2014). The economic downturn affected the entire supply chain due to the interconnections formed by its complex nature. Nevertheless, oilfield service companies are typically greatly affected by fluctuations in oil prices (T. Zhu, Balakrishnan, & da Silveira, 2019).

The specific characteristics of the oil service industry significantly influence the selection of suppliers. One fundamental factor is the industry's reliance on various suppliers, each contributing to a particular aspect of the production cycle (Muazu & Tasmin, 2017). These suppliers encompass human resources providers, equipment rental services, technology innovators, and safety compliance experts. Consequently, supplier selection becomes a nuanced process, requiring the evaluation of various attributes beyond the traditional cost and quality criteria (Haddad et al., 2021). Due to the hazardous nature of the industry's operations and its global reach, it is crucial to consider factors such as compliance with safety regulations, adaptability to remote locations, and the ability to mitigate environmental impacts when selecting suppliers. (Akinwale et al., 2018).

The challenges inherent to the oil service industry render conventional supplier selection approaches insufficient in addressing its unique needs (Akinwale et al., 2018). Conventional methods typically rely on standardised criteria that may not adequately account for the industry's intricacies. For instance, traditional approaches might overlook the need for suppliers to possess specialised safety certifications to operate in high-risk environments or maintain a swift response capacity in emergencies (Katırcıoglu et al., 2020). Moreover, the time-sensitive nature of the industry requires suppliers to be agile and adaptive to sudden changes in demand and operational conditions (Taleghani & Tyagi, 2017). Thus, a conventional approach emphasising rigid criteria may fail to capture the full spectrum of considerations essential for effective supplier selection in this dynamic context.

In light of these challenges, there is a pressing need for a more tailored and holistic approach to supplier selection in the oil service industry. By acknowledging the industry's unique characteristics and challenges and recognising that conventional methods may fall short in addressing these intricacies, researchers and practitioners can develop an approach that maximises the efficiency, safety, and resilience of the industry's supplier network. This research seeks to bridge this gap by formulating a specialised framework that captures the multifaceted dimensions of supplier selection within the oil service sector, ultimately contributing to its sustainable growth and performance.

2.2.Existing Supplier Selection Models and Their Limitations

Previous research has extensively explored supplier selection models across various industries, such as agri-food (Banaeian et al., 2018; Siakwah, 2017), automotive (Jain et al., 2018), pharmaceutical (Sabouhi et al., 2018), and Small and Medium Enterprises (SME) (Gupta & Barua, 2017). These models typically emphasize attributes such as pricing, quality, delivery, and reputation to facilitate effective supplier selection. For example, the agri-food sector prioritizes the quality and safety of raw materials, while the automotive industry emphasizes supply chain efficiency and just-in-time delivery. These models have significantly contributed to optimizing supplier selection processes and improving operational performance. However, the oil and gas sector neglected to consider their supply chain for a significant period (Tati, 2020). According to Mohammad (2008), interest in this topic among scholars and practitioners only arose when companies faced a crisis and discovered that 80% of their expenses were dedicated to supply chain systems. The literature currently contains numerous studies on prevalent difficulties and strategies in the oil and gas industry to address market unpredictability. The oil service industry presents unique challenges that require a nuanced approach to supplier selection. Unlike other industries, oil involves a range of activities such as exploration, drilling, production, refining, and distribution (Lu et al., 2019; Nispeling, 2015). Suppliers must be capable of navigating the unique demands of the industry, including safety compliance, environmental regulations, adaptability to remote and challenging environments, and managing high-cost potential risks (Vijayakumaran et al., 2020).

Despite the critical role of supplier selection in ensuring the oil service industry's efficient and safe operations, there is a noticeable lack of literature addressing this specialised area. The supplier selection models designed for other sectors cannot be directly transposed due to the distinct characteristics of the oil industry (Amindoust et al., 2012; Haddad et al., 2021). There is a limited amount of research that focuses specifically on supplier selection within the oil services industry. This has resulted in a significant gap in understanding and methodologies tailored to this sector's requirements. As a result, the oil services industry lacks comprehensive frameworks that consider the sector's unique attributes, which hinders the development of effective supplier selection strategies.

2.3.Supplier Selection Using TOPSIS

TOPSIS, which stands for Technique for Order Preference by Similarity to Ideal Solution, is a prominent distance-based MCDM/MADM (multi-criteria or multi-attribute decision-making) technique (Unutmaz Durmuşoğlu & Durmuşoğlu, 2021). It originates from the concept of a displaced ideal point from which the solution has the shortest distance is identified. The alternatives are ranked based on their distance from the ideal solution or positive ideal solution (PIS) and the negative-ideal solution (NIS) or anti-ideal solution or nadir in an n-dimensional Euclidean space.

TOPSIS simultaneously considers the distances to both PIS and NIS and ranks the preference order based on account of their relative closeness, which is a combination of these two distance measures. The core idea of the technique is that the distance function represents the decision makers' preference or utility. Therefore, the ranking of alternatives or variants can be made based on the combinations of distances.

Several studies have applied TOPSIS to supplier selection in innovative ways. For example, the study entitled TOPSIS Method for Developing Supplier Selection with Probabilistic Linguistic Information, investigates the probabilistic linguistic multiple attribute group decision-making

(MAGDM) with incomplete weight information (Lei et al., 2020). The authors propose a method where the linguistic term sets (LTSs) are transformed into probabilistic linguistic term sets (PLTSs), and an optimization model is built based on the fundamental idea of the conventional TOPSIS method.

Another study entitled "An integrated QFD and fuzzy TOPSIS approach for supplier evaluation and selection" presents a fuzzy MCDM method based on fusing and integrating fuzzy information and Quality Function Deployment (QFD) (Sharma & Tripathy, 2023). The authors demonstrate that their method can address multi-criteria decision-making scenarios in a computationally efficient manner. Furthermore, "Green Supplier Selection Using Intuitionistic Fuzzy AHP and TOPSIS Methods: A Case Study from the Paper Mills" discusses the application of intuitionistic multi-criteria supplier selection methods in a fuzzy environment (Demir & Koca, 2021). Meanwhile, a study entitled “Supplier selection to support environmental sustainability: the stratified BWM TOPSIS method” presents a novel criteria decision framework to assist supplier evaluation in organizations, taking into account different events that may occur in the future (Asadabadi et al., 2023).

Finally, the research entitled “Application of AHP and TOPSIS Method for Supplier Selection Between India and China in Textile Industry”, which applies AHP and TOPSIS methods for supplier selection in the textile industry (Sasi & Digalwar, 2015). The authors have considered some important criteria that affect the supplier selection process, namely product quality, service quality, delivery time and price. These studies illustrate how TOPSIS can be effectively applied in supplier selection, providing a robust and efficient decision-making framework.

2.4.Current Supplier Selection Techniques and Criteria in the Oil Industry

Supplier evaluation in the oil industry involves a careful assessment of the potential providers' capabilities and attributes. This approach ensures alignment with industry requirements and the ability to contribute to operational excellence. The techniques used involve a combination of qualitative and quantitative analysis, including assessments of technical competence, financial stability, reputation and compliance with health, safety and environmental (HSE) standards. The use of a comprehensive evaluation framework enables companies to make informed supplier decisions that reduce risk, improve performance and ensure compliance with stringent industry regulations.

The criteria selected for supplier evaluation reflect the diverse nature of the oil industry supplier landscape. Each criterion is carefully selected to meet the industry's distinct requirements and is informed by the findings of the literature review. Previous studies provide a comprehensive overview of various research studies on supplier selection methodologies in the oil service industry. For example, Wood used Fuzzy and Fuzzy TOPSIS methods to evaluate a range of attributes, including pricing, financial condition, reputation, risk, health, safety, and environment (HSE), quality/performance, and local content (Wood, 2016). Following this, Torabi & Boostani 2018 applied the Analytic Hierarchy Process (AHP) and Multi-Objective Linear Programming to assess similar attributes with the addition of environmental concerns (Torabi & Boostani, 2018).

In 2021, Fagundes et al. utilized Fuzzy Extended AHP to evaluate a broader set of attributes, including quality, delivery time, performance, location, flexibility, price, technology, financial aspects, economic factors, and environmental concerns(Fagundes et al., 2021). Similarly, Yazdi et al., in their 2022 study, employed Multi-Criteria Decision Analysis (MCDA) methods such as SWARA (Step-Wise Weight Assessment Ratio Analysis), COPRAS (Complex Proportional Assessment), WASPAS (Weighted Aggregated Sum Product Assessment), and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) to assess a variety of attributes including delivery/commitment, quality, price, reputation, flexibility, technical capability and experts, compatibility and relation (Yazdi et al., 2022).

In the same year, Haddad et al. used Fuzzy TOPSIS to evaluate Environmental Concerns/HSE (Haddad et al., 2021). Wang et al. applied Supply Chain Operations Reference model (SCOR) Metrics along with AHP and TOPSIS to assess delivery time and documentation accuracy in their 2018 study

(Wang, Huang, et al., 2018). Luzon & El-Sayegh in 2016 used AHP and Delphi methods to evaluate a comprehensive set of attributes including quality, delivery, performance history, warranties and guarantees, price, technical capability, reputation and geographical location (Luzon & El-Sayegh, 2016). Kaviani et al., in their 2020 study, used Grey Delphi and Grey Shannon along with grey Evaluation based on Distance from Average Solution (EDAS) to assess a wide range of attributes including Risks, Services Quality Lead time, Greenhouse gas emission Effort to establish cooperation Technical level Delivery Price Warranty Management Geography (Kaviani et al., 2020).

Sivapornpunlerd & Setamanit (2014) in their study applied AHP to evaluate quality delivery service flexibility. Gidiagba et al., (2023) in their study used Best Worst Method (BWM), TOPSIS and Delphi to assess a comprehensive set of attributes including HSE Quality Reliability Delivery Cost Availability Reputation Flexibility Technical Compatibility Waste Management System R&D Finance (Gidiagba et al., 2023). Finally, Wang et al., in their 2020 study used SCOR AHP DEA (Data Envelopment Analysis) to assess Reliability Ability Agile Effective Asset Management Costs (Wang et al., 2020). Yazdi et al., in another 2022 study used BWM MARCOS gray number to assess Flexibility Responsiveness Cost Quality Contracting Process Organization Green Standard Flexibility Project Characteristics (Yazdi et al., 2022).

However, despite the extensive research conducted in this field, a significant research gap persists in the oil service industry. Existing models do not comprehensively address the critical requirements of supplier selection and the unique challenges of this specific industry. This gap is particularly evident when considering the distinct attributes of the industry, such as direct involvement with occupational safety risks, reputation, delivery reliability. The carefully curated criteria framework captures the nuances of supplier selection within the oil services industry. Through the careful examination of these criteria, this research aims to provide a comprehensive understanding of supplier evaluation, thereby contributing to informed decision making that meets the complex demands and unique challenges of the industry.

3. Research Method

3.1.Research Stage

The methodology of this research is a systematic process designed to identify the optimal supplier in the oil services industry. It begins with the identification of potential suppliers, which is a comprehensive listing of all possible suppliers that could meet the needs of the industry. Following this, the definition of attributes for supplier selection is determined. These attributes are essentially the criteria that a supplier must meet to be considered suitable. They could include factors such as cost, quality, delivery time, and reputation.

The process then moves on to matrix normalization. This is a mathematical method used to compare suppliers on an equal basis, taking into account all the defined attributes. As the process progresses, it becomes clear that some attributes are more important than others. This is addressed through weighted normalization, which gives more importance or 'weight' to these key attributes. Finally, the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is used to determine the optimal supplier. This supplier is the one that best meets our needs based on our defined and weighted attributes.

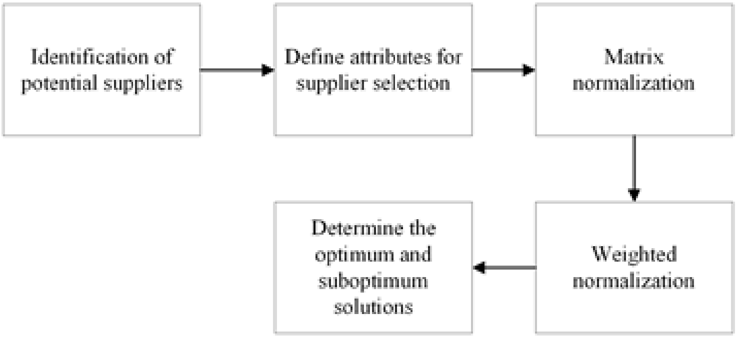

Fig. 1: The Proposed Framework.

3.2.Identification of Potential Suppliers

In the oil service industry, the identification of potential suppliers is a critical first step. This process involves pinpointing a subset of suppliers that meet specific criteria, making them indispensable to the industry's operations. These suppliers are often involved in high-stakes activities such as on-site service provision, transportation of personnel and equipment, direct engagement with occupational health risks, and association with potentially high-cost business ventures.

Among these critical suppliers are those providing human resources. These suppliers are responsible for staffing the industry with skilled professionals capable of carrying out complex tasks. They ensure that the industry has access to a pool of talent that can drive its operations. Medical service providers are another crucial category of suppliers. Given the occupational health risks associated with the oil service industry, these suppliers provide necessary medical support to ensure the safety and well-being of personnel.

Suppliers providing heavy machinery rentals are indispensable given the nature of operations in the oil service industry. These suppliers provide the necessary equipment for extraction and refinement processes, ensuring that operations run smoothly.

3.3.Modified TOPSIS Method

Supplier selection is the process used by organizations to identify, assess, and negotiate contracts with suppliers. A company's supplier selection procedure is an essential component that often consumes a significant amount of its financial resources (Peng & Selvachandran, 2018). Since the requirements for supplier selection and evaluation would vary significantly depending on the industry, in this study we propose a modified TOPSIS technique based on the circumstance of varying oil prices over time with its allocated weight. TOPSIS was developed by Hwang and Yoon based on the principle of relative closeness to an ideal solution (Gupta et al ,2019). In order to calculate the score for each attribute in the supplier evaluation process, which takes into account the importance of three different scenarios reflecting the state of oil prices, the TOPSIS collected data from interviews with supply chain experts in the oil services industry from different companies. F Four supply chain experts were interviewed to assess the importance of each criterion in three different scenarios: a pessimistic scenario (low oil prices), a realistic scenario (normal oil prices) and an optimistic scenario (high oil prices). Likert scales, the standard rating format for surveys, were used. A Likert rating scale was used to measure the items (Matas, 2018), which employs a set of five-point response anchors that are considered to be the most effective (Xu and Leung, 2018). The scale ranges from 1, indicating no importance, to 5, indicating utmost importance. According to Seaman &Allen (2007), supply chain professionals in the oil and gas services sector use a five-point scoring system to rate each criterion, ranging from least to most important. Ordinal data refers to the results obtained from Likert surveys. The main point of disagreement regarding Likert data is whether ordinal data should be treated as interval data when collected. Can parametric statistics, which require data to follow a bell-shaped distribution and make mathematical sense, be used to analyze the ordinal data generated by a Likert question? Although some argue that it is acceptable to use the mean and standard deviation as statistical measures for Likert data, the consensus among experts is that the mode, median, and interquartile range are the most appropriate methods for representing ordinal data (Stratton, 2018). Therefore, in this study, the mode approach will be used to determine the mean of ordinal data, taking into account the prevailing view.

3.3.1. Define Attributes for Supplier Selection

The evaluation of identified critical suppliers is a comprehensive process involving detailed analysis based on a set of pre-defined attributes. These attributes provide the benchmark against which each supplier is measured. These attributes were derived from the many literature reviews on the oil and gas business and then incorporated into industry tendering procedures. Wang et al. identified quality, responsiveness, delivery time, document accuracy, number of deliveries, pricing and qualitative factors for supplier evaluation in the oil and gas industry in 2018. The first attribute is documentation completeness. This is an assessment of whether the supplier has all the necessary documentation, which demonstrates their professionalism and adherence to industry standards.

Technical evaluation is another key attribute. This involves examining the supplier's technical capabilities to ensure that they can meet the specific requirements of the industry. Pricing is also an important factor. It's important to ensure that the supplier's pricing is competitive and offers good value for money. The historical health, safety and environmental (HSE) risk assessment attribute involves evaluating the supplier's past performance in terms of health and safety and its impact on the environment.

A broader risk analysis is also carried out to identify any potential risks associated with working with the supplier. The supplier's reputation in the marketplace is another important attribute. A good reputation can often be an indicator of quality service and reliability. Local content contribution assesses the extent to which the supplier contributes to the local economy, which can be an important factor in certain regions or countries.

Delivery performance assesses how well the supplier has delivered goods or services on time in the past. Warranty coverage assesses the warranties the supplier provides for its goods or services. Financial stability is a critical attribute that assesses whether the supplier is financially sound and therefore likely to be a reliable partner in the long term. Reliability and performance history assesses how reliable the supplier has been in the past and how well they have performed on previous contracts. By carefully evaluating these attributes, an informed decision can be made to ensure that the selected supplier is well-suited to meet the unique requirements of the oil services industry.

3.3.2. Matrix Normalization

The application of the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) in this research is a systematic process that helps to identify and prioritise the critical criteria for supplier selection in the oil services industry. This technique compares potential suppliers against ideal and anti-ideal benchmarks, providing a comprehensive ranking of criteria that takes into account both quantitative and qualitative aspects. The insights gained at this stage are invaluable and highlight the most important attributes in the industry context.

The implementation of TOPSIS starts with the formulation of a decision matrix. This matrix contains all the supplier attributes under consideration. It serves as a comprehensive representation of all potential suppliers and the attributes that define them. Equation (1.1) represents the first step in this process, where each element of the decision matrix is defined.

$$\mathrm{m} = \begin{bmatrix} x_{11} & \cdots & x_{1n} \\ \vdots & \ddots & \vdots \\ x_{m1} & \cdots & x_{mn} \end{bmatrix} \tag{0.1}$$

The decision matrix is then normalised. This step is crucial as it mitigates the influence of different scales of measurement between attributes, ensuring that comparisons between suppliers are fair and unbiased. This normalised decision matrix then serves as the basis for further analysis and evaluation in the supplier selection process. In essence, through a series of structured steps, TOPSIS provides a robust framework for evaluating and selecting suppliers in the oil services industry, taking into account a wide range of factors and ensuring that the selection process is thorough, fair and tailored to the unique requirements of the industry.

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}, \quad i = 1, 2, ..., m \quad \text{dan} \quad j = 1, 2, ..., n \tag{0.2}$$

3.3.3. Weighted Normalization

After normalising the decision matrix, the next step in the process is weighted normalisation. This step is crucial because it takes into account the varying importance of different attributes. Not all attributes are equally important in the supplier selection process. Some attributes carry more weight than others based on their relevance and impact on the supplier's overall performance. . Weighted normalisation involves assigning weights to each attribute in the decision matrix. These weights reflect the relative importance of each attribute in the supplier selection process. For example, an attribute such as 'delivery performance' might be considered more important than 'warranty coverage' and would therefore be given a higher weight. However, for this research, the weight assigned will be determined by taking into account fluctuations in oil prices and considering three situations for oil prices: realistic (when the price is normal), optimistic (when the price is high) and pessimistic (when the price is low). Each condition will have a different weight; the realistic situation will have a weight of 0.7, the pessimistic situation will have a weight of 0.2 and the optimistic situation will have a weight of 0.3.

This process ensures that the decision matrix accurately reflects the priorities of the oil service industry. It allows for a more nuanced and comprehensive assessment of potential suppliers, ensuring that the most critical attributes have a greater influence on the final decision.

In essence, weighted normalization refines the decision matrix to better align with the specific needs and priorities of the oil service industry, paving the way for a more informed and effective supplier selection process.

$$v_{ij} = r_{ij} \times w_j, \quad i = 1, 2, ..., m \quad \text{dan} \quad j = 1, 2, ..., n \tag{0.3}$$

3.3.4. Determine the Optimum and Suboptimum Solutions

After the weighted normalization process, the next step is to determine the optimal and suboptimal solutions. These solutions represent the best and worst attribute performances respectively. In other words, the optimal solution represents a supplier with the highest scores on all attributes, while the suboptimal solution represents a supplier with the lowest scores. Equations (1.4) and (1.5) are used to calculate these solutions. They provide a mathematical representation of the best and worst possible outcomes based on the weighted attributes.

$$A^* = \left\{ \max_{j \in C_b} v_{ij}, \min_{j \in C_c} v_{ij} \right\} = \{ v_j^* \mid j = 1, 2, \ldots, m \} \tag{0.4}$$

$$A^- = \left\{ \min_{j \in C_b} v_{ij}, \max_{j \in C_c} v_{ij} \right\} = \{ v_j^- \mid j = 1, 2, \ldots, m \} \tag{0.5}$$

By calculating the Euclidean distance, the separation measure quantifies the deviation between the alternatives and these ideal solutions.

$$S_i^* = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_{ij}^*)^2}, \quad j = 1, 2, \ldots, m \tag{0.6}$$

$$S_i^- = \sqrt{\sum_{j=1}^{m} (v_{ij} - v_{ij}^-)^2}, \quad j = 1, 2, \ldots, m \tag{0.7}$$

This is the basis for measuring the relative closeness to the ideal solution. As a result, vendors are ranked based on their proximity to the ideal solution, facilitating an informed decision-making process that addresses the unique needs and challenges of the industry.

3.3.5. Calculate Performance Score

After determining the optimum and suboptimal solutions, the last step is to calculate the performance score, the final stage of the TOPSIS method, which is the calculation of the performance score (Pi). This stage determines the relative performance of each criterion based on the calculated distances from the best and worst solutions.

$$P_i = \frac{S_i^-}{S_i^+ + S_i^-} \tag{1.8}$$

4. Result and Discussion

Supplier selection has become increasingly important to the oil services industry, with hundreds of suppliers required in many categories. The industry's current supplier selection process is based on a framework that evaluates suppliers against a set of criteria (Ng 2008; Bhattacharya et al 2010), with top suppliers being awarded (De Boer et al 2001). As a result, vendors need to decide on the attributes/criteria and the model to be used for evaluation. Many suppliers have been used by oil service companies to support their operations. However, this study focuses only on key suppliers.

The main objective of the modified TOPSIS methodology is to identify the most influential and critical criteria in the supplier selection process for the oil and gas service industry. To further enrich the decision-making process, interviews were conducted with four supply chain experts. In three different scenarios - a pessimistic scenario (when the oil price is low), a realistic scenario (when the oil price is average) and an optimistic scenario (when the oil price is high) - these experts were asked to rank the importance of each criterion. These hypothetical situations provide a thorough insight into the state of the market and allow for a more nuanced understanding of the supplier selection process. Likert scales, a standard survey rating format, were then used in these interviews. The respondents, supply chain experts in the oil and gas services sector, used five levels to rate each criterion from least to most important.

Table 1. Likert Scale

1	Not at all Important
2	Slightly Important
3	Important
4	Failry Important
5	Extremely/Very Important

The results of the Likert survey are referred to as ordinal data, which is a type of data that involves an order or ranking.

A point of contention about Likert data is whether ordinal data should be treated as interval data when this type of data is obtained. Parametric statistics, which rely on a typical bell-shaped distribution and mathematically meaningful data, can be used to examine the ordinal data produced by a Likert type question. While some argue that using the mean and standard deviation as statistical measures is acceptable for Likert data, most experts agree that the mode, median and quartiles are the best ways to express ordinal data. Therefore, in this study, the mode approach is used to calculate the mean of ordinal data, which means that the majority view is taken into account. This approach ensures that the results accurately reflect the collective opinion of the experts, thereby increasing the validity and reliability of the findings.

Table 2. The results of expert opinions on various criteria for supplier selection in the oil and gas service industry

Pessimistic							
Respondent	**Document Completion**	**Technical Evaluation**	**Pricing**	**HSE risk**	**Risk Analysis**	**Reputation**	**Local Content**
Expert 1	5	5	5	5	4	4	3
Expert 2	5	5	5	4	2	2	3
Expert 3	3	5	5	5	3	5	3
Expert 4	4	4	5	3	3	2	2

Pessimistic						
Respondent	**Delivery/Lead Time**	**Warranty**	**Financial**	**Reliability**	**Performance History**	**After Sales Support**
Expert 1	4	4	4	4	4	4
Expert 2	5	4	4	4	3	3
Expert 3	5	4	2	5	5	3
Expert 4	3	5	3	4	3	4

Optimistic							
Respondent	**Document Completion**	**Technical Evaluation**	**Pricing**	**HSE risk**	**Risk Analysis**	**Reputation**	**Local Content**
Expert 1	5	5	5	5	4	4	3
Expert 2	5	5	5	4	2	2	3
Expert 3	3	5	3	5	3	5	3
Expert 4	4	4	3	3	5	4	3

Optimistic						
Respondent	**Delivery/Lead Time**	**Warranty**	**Financial**	**Reliability**	**Performance History**	**After Sales Support**
Expert 1	4	4	4	4	4	4
Expert 2	5	4	4	4	3	3
Expert 3	2	4	2	5	5	3
Expert 4	5	5	3	4	5	4

Realistic							
Respondent	**Document Completion**	**Technical Evaluation**	**Pricing**	**HSE risk**	**Risk Analysis**	**Reputation**	**Local Content**
Expert 1	5	5	5	5	4	4	3
Expert 2	5	5	5	4	2	2	3
Expert 3	3	5	4	5	3	5	3
Expert 4	4	4	3	3	3	2	4

Realistic						
Respondent	**Delivery/Lead Time**	**Warranty**	**Financial**	**Reliability**	**Performance History**	**After Sales Support**
Expert 1	4	4	4	4	4	4
Expert 2	5	4	4	4	3	3
Expert 3	3	4	2	5	5	3
Expert 4	3	5	3	5	3	4

Table 2 shows the results of the experts' opinions on various criteria for supplier selection in the oil and gas services industry. The experts rated each criterion on a scale of 1 to 5, with 1 being "not at all important" and 5 being "very important". The ratings were given under three scenarios: pessimistic, optimistic and realistic. In the pessimistic scenario, where oil prices are low, the experts seem to place a high importance on document completion, technical evaluation and pricing, with most experts giving these criteria a score of 5. HSE risk and risk analysis also appear to be significant, with scores mostly around 4 and 5. Other criteria, such as local content, delivery/lead time, warranty, finance, reliability, performance history and sales support, received mixed scores, indicating differing opinions among the experts.

In the optimistic scenario, where the oil price is high, the pattern of ratings is similar to the pessimistic scenario. However, there are some differences. For example, Expert 3 gave a lower score of 3 to pricing and a score of 2 to delivery/lead time. Expert 4 also gave a higher score of 5 to risk analysis and warranty. In the realistic scenario, where the oil price is regular, the pattern of ratings is again similar to the other two scenarios. However, Expert 3 gave a lower score of 4 to pricing and Expert 4 gave a higher score of 4 to local content.

Table 3. The collective opinion of the experts on various supplier selection criteria, calculated using the mode approach

Supplier criteria	Pessimistic	Optimistic	Realistic
Document Completion	5	5	5
Technical Evaluation	5	5	5
Pricing	5	5	5
HSE	5	5	5
Risk Analysis	3	4	3
Reputation	2	4	2
Local Content	3	3	3

Delivery/Lead Time	5	5	3
Warranty	4	4	4
Financial	4	4	4
Reliability	4	4	4
Performance History	3	5	5
After Sales Support	4	4	4

Table 3 presents the collective opinion of the experts on various supplier selection criteria in the oil and gas services industry, calculated using the mode approach. This approach ensures that the results accurately reflect the majority view, thereby increasing the validity and reliability of the results. Documentation, technical evaluation, pricing and HSE are the most important in all three scenarios - pessimistic, optimistic and realistic - with a score of 5. This indicates that most experts consider these criteria to be very important, regardless of the oil price scenario. Risk analysis and reputation received lower scores of 3 and 2 in the pessimistic and realistic scenarios, but their importance increased in the optimistic scenario with a score of 4. This suggests that these criteria become more important when the oil price is high.

Local content maintained a consistent score of 3 across all scenarios, indicating that it is considered necessary by the experts. Delivery/lead time received a high score of 5 in the pessimistic and optimistic scenarios but decreased in importance in the realistic scenario to a score of 3. This suggests that delivery timeliness becomes less critical at normal oil prices. Warranty, finance, reliability and sales support all received a consistent score of 4 across all scenarios, indicating that most experts consider them reasonably necessary. Performance history received a score of 3 in the pessimistic scenario, but its importance increased to a score of 5 in the optimistic and realistic scenarios. This suggests that the supplier's past performance becomes critical when the oil price is average or high.

Table 4. The results of Weighted Normalised Matrix calculations

	Pesimistic	**Optimistic**	**Realistic**
Document Completion	0.067	0.092	0.245
Technical Evaluation	0.067	0.092	0.245
Pricing	0.067	0.092	0.245
HSE risk	0.067	0.092	0.245
Risk Analysis	0.040	0.092	0.147
Reputation	0.026	0.073	0.098
Local Content	0.040	0.055	0.147
Delivery/Lead Time	0.067	0.092	0.147
Warranty	0.053	0.073	0.196
Financial	0.053	0.073	0.196
Reliability	0.053	0.073	0.196
Performance History	0.040	0.092	0.147
After Sales Support	0.053	0.073	0.196

The next stage is to calculate the Weighted Normalized Matrix using equations 1.1-1.3. Table 4 shows the results of the Weighted Normalized Matrix calculations in the TOPSIS method for supplier selection in the oil and gas services industry. These calculations are performed under three scenarios: pessimistic, optimistic and realistic. In the pessimistic scenario, Document Completion, Technical Evaluation, Pricing and HSE Risk have the highest values, indicating that these criteria significantly influence supplier selection when the oil price is low.

In the optimistic scenario, the same four criteria - document completion, technical evaluation, pricing and HSE risk - also have the highest scores, suggesting that these criteria remain the most influential even when the oil price is high. However, the situation changes in the realistic scenario. Although Document Completion, Technical Evaluation, Pricing and HSE Risk still have high scores, their influence is less dominant than in the other two scenarios. Instead, other criteria such as warranty, finance, reliability and sales support become more important, as indicated by their increased values.

Table 5. The results of the calculation of the ideal best (Si+) and ideal worst (Si-) values using Euclidean Distance

	Si+	**Si-**
Document Completion	0	0.156
Technical Evaluation	0	0.156
Pricing	0	0.156
HSE risk	0	0.156
Risk Analysis	0.178	0.062
Reputation	0.153	0.266
Local Content	0.108	0.050
Delivery/Lead Time	0.098	0.073
Warranty	0.054	0.103
Financial	0.054	0.103
Reliability	0.054	0.103
Performance History	0.101	0.062
After Sales Support	0.054	0.103

The next step is to calculate the ideal best and worst values using Euclidean Distance, as shown in equations 1.4-1.7. Table V shows the results of the calculation of the ideal best (Si+) and ideal worst (Si-) values using Euclidean Distance in the TOPSIS method. The calculation of the ideal best and ideal worst values is to determine the optimal and least optimal solutions based on the criteria.The ideal best value (Si+) represents the solution that maximizes the benefit criteria and minimizes the cost criteria. Conversely, the ideal worst value (Si-) represents the solution that minimizes the benefit criteria and maximizes the cost criteria.

The results show that for criteria such as Document Completion, Technical Evaluation, Pricing, and HSE Risk, the ideal best values are 0, and the ideal worst values are relatively high. This indicates that these criteria are very close to the optimal solution in the supplier selection process. On the other hand, criteria such as risk analysis, reputation and local content have higher ideal best values and lower ideal worst values. This suggests that these criteria are further away from the optimal solution and closer to the least optimal solution.

Table 6. The results of the performance score

	Pi	Rank
Document Completion	1	1
Technical Evaluation	1	2
Pricing	1	3
HSE risk	1	4
Risk Analysis	0.26	13
Reputation	0.63	9
Local Content	0.31	12
Delivery/Lead Time	0.42	10
Warranty	0.65	5
Financial	0.65	6
Reliability	0.65	7
Performance History	0.38	11
After Sales Support	0.65	8

The last step is the calculation of the performance score. Table 6 shows the results of the last step of the TOPSIS method, the calculation of the performance score (Pi). This stage determines the relative performance of each criterion based on the calculated distances from the best and worst solutions. The performance score for each criterion is calculated using equation 1.8.

The results show that the criteria of Document Completion, Technical Evaluation, Pricing, and HSE Risk all have a performance score of 1. Therefore, these criteria have the highest performance score of 1 and are ranked from 1 to 4, respectively. This indicates that these criteria are the most influential in supplier selection and should be prioritized.

On the other hand, criteria such as risk analysis, reputation and local content have lower performance scores, indicating that they are further away from the ideal best solution and closer to the ideal worst solution. Based on these results, the decision can be made to prioritize suppliers with high scores on Document Completion, Technical Evaluation, Pricing and HSE Risk, as these are the most influential criteria in the supplier selection process. Despite their lower performance scores, suppliers who score well on the other criteria should also be considered to ensure a balanced and comprehensive supplier selection process.

Warranty ranks 5th with a performance score of 0.656425756, suggesting that it is also an important criterion, but not as critical as the top four. The remaining criteria - risk analysis, reputation, local content, delivery/lead time, financial, reliability, performance history and sales support - have no assigned ranks. However, their performance scores suggest that they are also important and should be considered in the supplier selection process, albeit with a lower priority than the ranked criteria.

The impact of these rankings on decision-making would be a more focused and effective supplier selection process. By prioritizing suppliers that score highly on the top-ranked criteria, the industry can ensure that it selects the most suitable suppliers, leading to improved operational performance and cost efficiency. However, it is important to note that these rankings are based on mathematical calculations and expert opinion and may not reflect the views of all industry stakeholders. Therefore, these results should be used as a guide and supplemented with other relevant information when selecting suppliers.

4. Conclusion and Recommendations

In conclusion, this study's modified TOPSIS and expert opinion-based model provides a comprehensive protocol for selecting oil suppliers according to the sector's specific needs in terms of occupational risks and demand fluctuations. The results show that document, technical, price and safety criteria are the most influential, while highlighting the relevance of risk, reputation and local content factors to holistic decision making. Industry practitioners can use these findings to make strategic sourcing decisions that enable operational resilience. However, translating the mathematical calculations into on-the-ground selection processes remains an implementation challenge. As the framework is constrained by the limited supplier-related dataset, future research should validate the findings across larger, multi-country samples. Overall, this research represents a starting point for redefining oil services supplier evaluation through evidence-based and context-specific techniques.

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