Library Progress International *Print version ISSN 0970 1052*
Vol.44 No. 3, Jul-Dec 2024: P. 19526-19533 *Online version ISSN 2320 317X*

Original Article *Available online at www.bpasjournals.com*

Selection of Sustainable Subsurface Suppliers using AHP-TOPSIS Method in Upstream Oil and Gas Industry

Dicky Fitriyandi[1*] and Suparno[2]

[1]Student, Interdisciplinary School of Management and Technology, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia
[2]Professor Interdisciplinary School of Management and Technology, Sepuluh Nopember Institute of Technology, Surabaya, Indonesia
[1]dicky.fitriyandi@gmail.com, [2]suparno@its.ac.id
[1]0009-0007-3731-4897, [2]0009-0000-5030-1969

How to cite this article: Dicky Fitriyandi, Suparno (2024) Selection of Sustainable Subsurface Suppliers using AHP-TOPSIS Method in Upstream Oil and Gas Industry. *Library Progress International*, 44(3), 19534-19571.

ABSTRACT

This study addresses the critical role of subsurface supplier selection in the upstream oil and gas industry, emphasizing the integration of sustainability principles aligned with UN's Sustainable Development Goals (SDGs) and the Strategic Plan of the Oil and Gas Directorate General by the Ministry of Energy and Mineral Resources of the Republic of Indonesia. The selection of subsurface suppliers especially in the context of drilling operations for well development at Upstream Oil and Gas Company X needs to incorporate comprehensive sustainability principles to avoid negative impacts on product and service quality, as well as the social and environmental responsibilities of the company that arise from the supply chain. The research employs the combined AHP-TOPSIS method to identify and assess criteria and sub-criteria factors influencing sustainable subsurface supplier selection. Four criteria have been divided into 13 sub-criteria to evaluate the subsurface suppliers. Using the AHP method, the study determines that the criteria with the highest weights obtained are Environment (44%), Economy (34%), Social (16%), and Ethics (6%), while the sub-criteria with the weights are Environmental Management Systems (15.10%), Occupational Health & Safety System (14.44%), followed by Code of Conduct (12.48%) and Quality (11.77%) with a consistency ratio < 0.1. The TOPSIS method is then applied to rank alternative subsurface suppliers, revealing that supplier S5 attains the highest preference value of 0.6750. Data collection involved observation, discussion, questionnaires, and literature studies, targeting professional experts in Upstream Oil and Gas Company X in Indonesia. The results emphasize the robustness of the TOPSIS method through sensitivity analysis, confirming that alterations of ±2% do not impact the ranking of alternative subsurface suppliers. This study provides a comprehensive approach to sustainable subsurface supplier selection, contributing to the industry's adherence to sustainability goals and responsible supply chain practices.

Index Terms— AHP-TOPSIS, sustainable supplier selection, sustainable supply chain, criteria, subsurface, drilling, upstream oil and gas

Introduction

Supplier selection is a major concern for every manufacturing or service industry because it has a significant impact on the goods or services provided by the company to achieve high product quality, supply chain efficiency and organizational effectiveness. The main aim of selecting suppliers is to reduce purchasing costs and increase business competitiveness [12]. The existence of UN's Sustainable Development Goals (SDGs) and the Strategic Plan of the Oil and Gas Directorate General [10], encourage companies to prioritize the thorough integration of social and environmental sustainability factors in the supplier selection process ([2]; [20]).

The subsurface supplier selection procedure carried out by the upstream. However, it is felt that environmental factors and other criteria factors such as social performance and ethics have not been implemented comprehensively. This shows that upstream oil and gas industry overall, selecting suppliers that do not apply sustainability principles can have a significant negative impact on the company, society and the environment. Therefore, it is important for companies to pay attention to socially and environmentally responsible business practices in their supplier selection ([7]; [11]).

Supplier selection needs to pay attention to various criteria that are taken into account, both tangible and intangible, so that they can be used as a reference in the decision making process. The supplier selection process is related to the multi-criteria decision making (MCDM) problem. Some commonly used methods include The Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), Analytic Network Process (ANP), and Analytic Hierarchy Process (AHP), FAHP, FTOPSIS, and Entropy ([21]; [19]).

Based on several previous studies that have been carried out in supplier selection, such as research by [9] which used the AHP-TOPSIS method in selecting sustainable suppliers in electronics companies, which shows that economic factors are still an influencing factor in selecting sustainable suppliers. Apart from that, research [18] integrated the AHP and TOPSIS methods in selecting Green Supplier Selection in offset printing companies. The difference with the research that will be carried out is that this research was carried out to select subsurface suppliers who have implemented the concept of sustainability at the Upstream Oil and Gas Company X.

In general, the AHP method is used to provide a weight assessment for each important criterion by breaking down its constituent parts and providing a hierarchical structure. However, even though the AHP method provides good robustness results, using the AHP method requires time in pairwise comparisons. Meanwhile, the TOPSIS method is basically based on the concept that the best alternative must have the shortest distance from the positive ideal solution (PIS) and the farthest distance from the negative ideal solution (NIS). TOPSIS is relatively simple which can provide a measure of relative assessment between alternatives. However, the TOPSIS method itself also has shortcomings in determining subjective weights against existing criteria and has low robustness. Therefore, the AHP and TOPSIS models are combined to select potential suppliers who have implemented the sustainability concept. The AHP value based on the weighted results of each criterion will be used as TOPSIS input in determining the ranking of alternative suppliers. The AHP assessment results are then evaluated by TOPSIS to find the best alternative that is closest to the positive ideal solution and farthest from the negative ideal solution. Research conducted by [13] shows that the combined AHP-TOPSIS method is an efficient decision making method because AHP is a subjective decision making method and has inconsistencies. TOPSIS, on the other hand is a model that provides a ranking of alternatives based on the weight given to each criterion. This combination of methods will increase the subjectivity of TOPSIS by combining it with AHP to receive criteria weights thereby producing an optimal and efficient decision making method.

The objective of this research is to identify the criteria and sub-criteria factors that influence the sustainable subsurface supplier selection, assess the weight of each important criterion from existing procedures, and to determine the priority order of suppliers.

Based on the explanation above, the researcher intends to carry out research on sustainable subsurface supplier selection by developing existing procedures in Upstream Oil and Gas Company X in Indonesia by adding criteria or sub-criteria factors using the combined AHP-TOPSIS method.

I. Literature Review

2.1. Sustainable Supply Chain Management

In general, Supply Chain Management is a form of approach that can be used effectively and efficiently to integrate suppliers, factories, warehouses and marketing places so that the products produced and the distribution process can be tracked easily and optimally [3]. Supply Chain Management will optimize the performance of the entire series of processes effectively and efficiently involving all elements such as production, raw material procurement, marketing, operations, distribution, finance and services from upstream to downstream so that it can provide added value for consumers and increase company profits [17].

Meanwhile, in sustainable supply chain management, organizations need to consider environmental and social impacts when designing and optimizing their supply chains. Supply chain management as managing the flow of materials, information, and capital, as well as fostering collaboration with companies in the supply chain, to achieve sustainability across economic, environmental, and social dimensions [9]. [15] in their book explains that Supply Chain Management is a process for carrying out or rethinking the planning and management of production operations systems within a company with the aim of creating more agile and flexible capabilities that will be in line with efficiency, maximizing customer satisfaction and governance. good and sustainable management.

2.2. Sustainable Supplier Selection

Suppliers are individuals or bodies who have business cooperation relationships and play an important role

in supplying products or services to companies to carry out the production process. The importance of this role requires companies to carry out supplier selection or supplier selection [5]. Sustainable supplier selection is a critical and strategic activity in supply chain management due to the pivotal role suppliers play upstream in the supply chain [11]. This supplier selection process is very important to increase the company's competitiveness, and requires an assessment of different alternative suppliers based on different criteria [16].

When evaluating supplier performance, factors such as price, flexibility, and quality are usually the most used parameters in the selection process. However, recently apart from these parameters, the purchasing process has become more complex due to the linkage of sustainability which plays an important role in the supply chain according to the pressures of the environmental and social pillars. For achieving sustainable performance, supplier selection is considered more crucial than supplier integration and development [8].

2.3. Sustainable Supplier Selection Criteria

Sustainable supply chains must be able to address environmental and social risks in various geographic areas with concentrated upstream suppliers, all while preserving the financial stability of the chain. The initial stage to start a good relationship with suppliers is selecting suppliers to reduce the impact of risks that may arise [8]. According to [9], the criteria for supplier selection in the sustainability dimension are described in the next section.

2.3.1. Economic Factors

In various types of business fields, the main goal is to make a profit and therefore, traditional economic factors remain the main consideration in selecting suppliers such as quality, price, delivery time and others.

2.3.2. Environmental Factors

Industrialization has caused a lot of pollution, so companies need to have supply chains that do not damage the environment and preserve the ecology. Green procurement strategies contribute significantly in addressing these aspects in the supply chain such as eco-design, resource reduction and consumption, environmental management systems, and others.

2.3.3. Social Factors

The social perspective involves the management of social resources, including social values and human resources. Social factors are an important dimension of sustainability that involves various stakeholders with different goals, and is a challenge. Social factors include occupational health & safety systems, and corporate social responsibility (CSR), education & training, and others.

2.3.4. Ethical Factors

To be able to qualify as a sustainable supplier, suppliers need to maintain high ethical standards in addition to meeting social and environmental criteria. Ethical factors include code of conduct (CoC), conflict of interest (CoI), transparency in accounting and business, and others.

The hierarchical structure model for sustainable subsurface supplier selection in this paper is shown in Figure

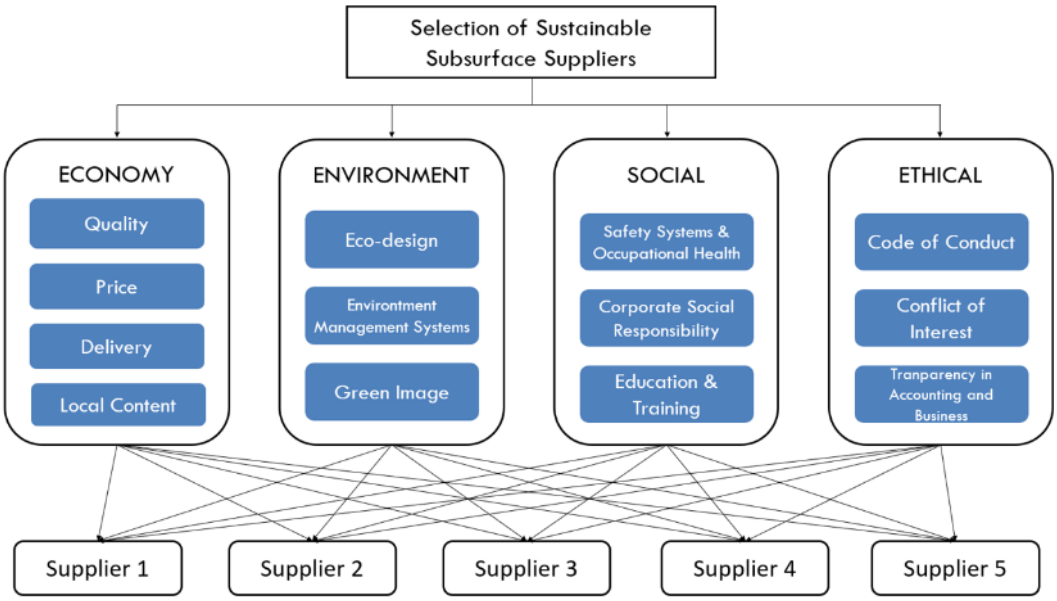

Figure 1. Hierarchical Structure Model for Selection of Sustainable Subsurface Supplier**Research methods**

3.1. Methodology Framework

The research methods used to collect data were observation, questionnaires and literature study. The data obtained will then be processed using the combined AHP-TOPSIS method. The decision making process uses AHP to provide an assessment of the importance of each criterion and determine preferences for each decision alternative considering all criteria. Meanwhile, the TOPSIS method is used to evaluate alternatives based on the alternative priority scale which is measured by the distance between the positive ideal solution and the negative ideal solution.

The proposed methodology framework for sustainable subsurface supplier selection is shown in Figure 2.

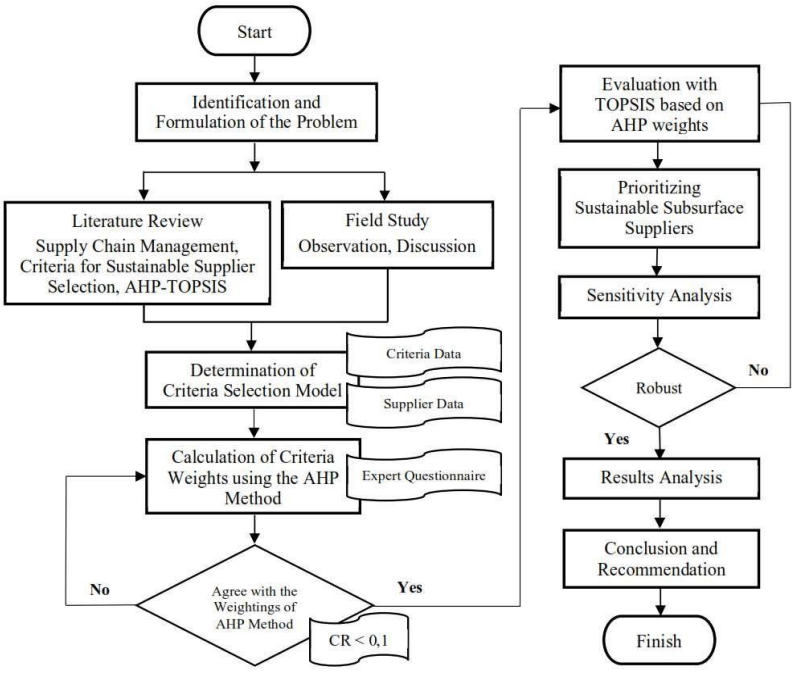

Figure 2. Research Flowchart for Selection of Sustainable Subsurface Supplier

Table 1.
Profile Expert

Experts	Experience	Division	Designation
Expert 1	16 years	Drilling and Well Intervention (Subsurface)	Senior Planning / Assistant Manager
Expert 2	15 years	Procurement and Supply Chain Management	Assistant Manager
Expert 3	13 years	Communication Relation Community	Senior Coordinator

AHP-TOPSIS Calculation

AHP was developed by Saaty (1977, 1990). AHP facilitates decision-making by performing pairwise comparisons and leveraging expert assessments to establish a priority scale, helping to determine priorities in complex problem-solving scenarios. According to [9], AHP is a method used by decision makers to categorize important criteria by breaking down the constituent parts and providing a hierarchical structure to complex problems.

TOPSIS is a method developed by Hwang and Yoon in 1981. The TOPSIS method is one of the most frequently used multi-criteria decision analysis methods. In this method, the optimal alternative is the one that is nearest to the positive ideal solution (PIS) and furthest from the negative ideal solution (NIS). PIS is an alternative hypothesis that maximizes benefit criteria while minimizing cost criteria. In contrast, NIS maximizes cost criteria while minimizing benefit criteria [4].

The steps in selecting sustainable subsurface suppliers in this research using the combined AHP-TOPSIS method are as follows ([9]; [8]; [1]):

Preparation of a hierarchical structure of the problem.

Building a criteria decision matrix with pairwise comparison.

The alternative weights for each criterion are aligned in one column/matrix to see the whole.

$$C_{ij} = [C_{11}\, C_{12}\, C_{13} \cdots C_{1n}\, C_{21}\, C_{22}\, C_{23} \cdots C_{2n} \vdots \vdots \vdots \$ \vdots C_{n1}\, C_{n2}\, C_{n3} \cdots C_{nn}] \quad (1)$$

where;

C_{ij} shows the comparative importance of the i[th] attribute with respect to the j[th] attribute vis-à-vis each other.

This matrix is created based on research data, namely an assessment of the relative importance of two elements at a certain level in relation to the level above it from respondents and discussions from experts. The Saaty's pairwise comparison scale can be seen in Table 2.

Table 2.

Scale of Pairwise Comparison for AHP

Level of Importance	Pairwise Comparisons
1	Both criteria have the same influence
3	Moderate importance of one item over another
5	Strong importance of one item over another
7	Very strong importance of one item over another
9	Extreme importance of one item over another
2,4,6,8	If there is doubt between two adjacent assessments
Reciprocals	Values of inverse comparisons
Decimals	Values of intermediate importance

Source: [6]

If there are two or more respondents' assessment results, the Geometric Mean is carried out to calculate the average of the paired assessments. The target respondents used in determining opinions regarding criteria based on the AHP method are professional experts who have many years of experience in their fields in the functions of Drilling and Well Intervention (Subsurface), Procurement and Supply Chain, and Communication Relations & Community Involvement Development. The profile of experts is shown in Table 1. This is done because AHP only requires one answer for the comparison matrix. The geometric mean formula is mathematically formulated as follows:

$$GM = \sqrt[n]{X1.X2 \dots X_n} \quad (2)$$

where;
GM = Geometric Mean
$X1, X2, \dots, X_n$= assessment weights 1st, 2nd, 3rd, …., n
n = number of n (order)

The decision matrix is then normalized using the following formula.

$$m_{ij} = \frac{x_{ij}}{\sum_{j=1}^{n} x_{ij}} \quad (3)$$

Calculate the priority weight for each criterion or sub-criteria in the AHP using the following formula.

$$w_{ij} = \sum_{j=1} \frac{m_{ij}}{n} \quad (4)$$

where;
i = 1,2,3...n
j = 1,2,3,...n

Determine the Consistency Ratio (CR), where the CR value is < 0.1, then the weight is declared consistent.

$$CR = \frac{CI}{RI} \quad (5)$$

where;
CR = Consistency Ratio
RI = Random Index

To determine the Consistency Index (CI) value, calculations are carried out, namely:

a. Multiplication of weights with a normalized matrix
b. The total summation of weight multiplication with a normalized matrix
c. Comparison between total value and initial weight
d. Determine the maximum eigenvalue which is the average value of all comparisons of the total value with the initial weight

$$CI = \frac{\lambda_{max} - n}{n-1} \quad (6)$$

where;
CI = Consistency Index
λ_{max}= maximum eigenvalue
n = matrix order

The Random Index (RI) value has been determined based on the rules listed in Table 3.

Table 3.
Random Index Value

Number of Criteria	Random Index
1	0
2	0
3	0.52
4	0.89
5	1.11
6	1.25
7	1.35
8	1.40
9	1.45
10	1.49
11	1.52
12	1.54

Building a normalized decision matrix (r_{ij})

This stage aims to normalize the matrix () to obtain comparable values. The following is the formula used to find the normalized value (r_{ij})

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \quad (7)$$

where;

x_{ij} = decision matrix

r_{ij} = normalized matrix

i= row (alternative)

j= column (criteria)

m= number of alternatives

The weighted normalized matrix is determined by multiplying each column of the matrix by the weight obtained with AHP.

$$v_{ij} = x r_{ij} w_j \quad (8)$$

where;

r_{ij} = normalized matrix

w_j = j[th] weight

v_{ij}= weighted normalized matrix

The positive ideal solution and negative ideal solution are calculated using the formula shown below.

$$A^+ = \{(\sum_i^{max} v_{ij}|jsJ), (\sum_i^{min} v_{ij}|jsJ'| = 1, 2, \dots m\} = \{v_1^+, v_2^+, v_3^+, \dots v_n^+\} \quad (9)$$

$$A^- = \{(\sum_i^{min} v_{ij}|jsJ), (\sum_i^{max} v_{ij}|jsJ'| = 1, 2, \dots m\} = \{v_1^-, v_2^-, v_3^-, \dots v_n^-\} \quad (10)$$

where;

J= (j = 1,2….n)/j is associated with favorable attributes and J' = (j = 1.2,…..n)/j is associated with unfavorable attributes. The maximum value of the benefit attribute and the minimum value of the cost attribute are taken for a positive ideal solution, while the minimum value of the benefit attribute and the maximum value of the cost attribute are taken for a negative ideal solution.

Calculate the distance to positive and negative ideal solutions

The formula for calculating the distance between alternative one with a positive ideal solution and a negative ideal solution is done using the following formula:

$$D_i^+ = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \quad (11)$$

$$D_i^- = \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \quad (12)$$

where;

v_{ij}= normalized matrix

v_j^*= jth positive ideal solution

Calculating relative proximity

This stage is the final stage to find the relative closeness value of each alternative to the ideal solution. The following is the formula for obtaining the relative closeness value:

$$V_i = \frac{D_i^-}{D_i + D_i} \quad (13)$$

A set of alternatives is then given a rank order based on the highest to lowest relative closeness value (V_i). The best decision alternative will show relative closeness (V_i) with the highest relative closeness value.

3.2. Sensitivity Analysis

Finally, to validate the robustness of the sustainable subsurface supplier ranking results, a sensitivity analysis is performed by adjusting the weights of the criteria [14]. Sensitivity analysis is carried out by increasing and decreasing the weight of the dominant criteria while the weights of other criteria are adjusted proportionally, then re-ranking the priorities of sustainable subsurface suppliers using the TOPSIS method. In the analysis, the weight of each sub-criterion is changed by increasing or decreasing the weight of each sub-criteria by 2% because the smallest criteria weight is 3%, thereby preventing sub-criteria that have a weight below 1% when lowered.

II. RESULTS AND DISCUSSION

4.1. Criterion Data

The criteria and sub-criteria in the decision to select a subsurface supplier were obtained through discussions with experts and also obtained from the company. These criteria include economic (C1), environmental (C2), ethical (C3) and social (C4) criteria. Meanwhile, the sub-criteria used according to each criterion include:

- Economy: Quality (C11), Price (C12), Delivery (C13) and Local Content (C14)
- Environment : Eco-design (C21), Environment Man. System (C22) and Green Image (C23)
- Ethics: Safety System & Occuputanional Health (C31), Corporate Social Responsibility (C32) and Education & Training (C33)
- Social: Code of Conduct (C41), Conflict of Interest (C42) and Transparency in Accounting and Business (C43)

The criteria data was taken from five different suppliers and then arranged in a table as follows.

4.2. Criteria and Subcriteria Weighting

4.2.1. Pairwise Comparison

Using the Geomatric Mean formula above, the results obtained are listed in the tables for each criteria and sub-criteria as follows.

A. Level of Importance between Criteria and Subcriteria

1. Expert Assessment Criteria

Table 4.

Pairwise Comparison of the Criteria

Expert 1 Questionnaire				
Criteria	C1	C2	C3	C4
C1	1	5	3	7
C2	1/5	1	3	5
C3	1/3	1/3	1	5
C4	1/7	1/5	1/5	1
Expert 2 Questionnaire				
Criteria	C1	C2	C3	C4
C1	1	1/3	3	5
C2	3	1	3	5
C3	1/3	1/3	1	3
C4	1/5	1/5	1/3	1
Expert 3 Questionnaire				
Criteria	C1	C2	C3	C4
C1	1	1/7	7	3
C2	7	1	5	7
C3	1/7	1/5	1	7
C4	1/3	1/7	1/7	1

2. Expert Assessment Sub-criteria

Table 5.
Pairwise Comparison of the Sub-criteria Economic

Expert 1 Questionnaire				
Sub-criteria	C11	C12	C13	C14
C11	1	1/9	1	7
C12	9	1	5	7
C13	1	1/5	1	7
C14	1/7	1/7	1/7	1
Expert 2 Questionnaire				
Sub-criteria	C11	C12	C13	C14
C11	1	7	5	5
C12	1/7	1	1	1/3
C13	1/5	1	1	3
C14	1/5	3	1/3	1
Expert 3 Questionnaire				
Sub-criteria	C11	C12	C13	C14

C11	1	5	5	5
C12	1/5	1	3	3
C13	1/5	1/3	1	1/5
C14	1/5	1/3	5	1

Table 6.
Pairwise Comparison of the Sub-criteria Environmental

Expert 1 Questionnaire			
Sub-criteria	C21	C22	C23
C21	1	1/7	1/7
C22	7	1	7
C23	7	1/7	1
Expert 2 Questionnaire			
Sub-criteria	C21	C22	C23
C21	1	1	3
C22	1	1	1
C23	1/3	1	1
Expert 3 Questionnaire			
Sub-criteria	C21	C22	C23
C21	1	1/7	1/3
C22	7	1	3
C23	3	1/3	1

Table 7.
Pairwise Comparison of the Sub-criteria Social

Expert 1 Questionnaire			
Sub-criteria	C31	C32	C33
C31	1	7	1
C32	1/7	1	1/3
C33	1	3	1
Expert 2 Questionnaire			
Sub-criteria	C31	C32	C33
C31	1	7	3
C32	1/7	1	1
C33	1/3	1	1
Expert 3 Questionnaire			
Sub-criteria	C31	C32	C33

C31	1	7	1
C32	1/7	1	1/3
C33	1	3	1

Table 8.
Pairwise Comparison of the Sub-criteria Ethical

Expert 1 Questionnaire			
Sub-criteria	C41	C42	C43
C41	1	1	1
C42	1	1	1
C43	1	1	1
Expert 2 Questionnaire			
Sub-criteria	C41	C42	C43
C41	1	3	1
C42	1/3	1	1
C43	1	1	1
Expert 3 Questionnaire			
Sub-criteria	C41	C42	C43
C41	1	5	5
C42	1/5	1	5
C43	1/5	1/5	1

B. Geomatric Mean

The data on the level of importance of each expert and the results of Geometric Mean calculations for each criterion and sub-criteria are as follows.

Table 9.
Geometric Mean of the Criteria

Criteria	C1	C2	C3	C4
C1	1	0.6198	3.9790	4.7177
C2	1.6134	1	3.5569	5.5934
C3	0.2513	0.2811	1	4.7177
C4	0.2120	0.1788	0.2120	1
Total	3.0767	2.0797	8.7479	16.0288

Table 10.
Geometric Mean of the Subcriteria Economic

Sub-criteria	C11	C12	C13	C14
C11	1	1.5726	2.9240	5.5934
C12	0.6359	1	2.4662	1.9129
C13	0.3420	0.4055	1	1.6134
C14	0.1788	0.5228	0.6198	1
Total	2.1567	3.5008	7.0100	10.1198

Table 11.
Geometric Mean of the Subcriteria Environmental

Sub-criteria	C21	C22	C23
C21	1,0000	0.2733	0.5228
C22	3.6593	1,0000	2.7589
C23	1.9129	0.3625	1,0000
Total	6.5722	1.6357	4.2817

Table 12.
Geometric Mean of the Subcriteria Ethics

Sub-criteria	C41	C42	C43
C41	1,0000	2.4662	1.7100
C42	0.4055	1,0000	1.7100
C43	0.5848	0.5848	1,0000
Total	1.9903	4.0510	4.4200

Table 13.
Geometric Mean of the Subcriteria Social

Sub-criteria	C31	C32	C33
C31	1,0000	7,0000	1.4422
C32	0.1429	1,0000	0.4807
C33	0.6934	2.0801	1,0000
Total	1.8362	10.0801	2.9230

4.2.2. Normalized Matrix

The next stage is normalization of the geometric mean result matrix on the criteria and sub-criteria. Normalization is carried out by dividing each data by the total of each column so that each data will have a value between 0 and 1 which if added together will total the same as 1. The results are shown in the tables below.

Table 14.
Normalization of Criteria Values

Criteria	C1	C2	C3	C4
C1	0.3250	0.2980	0.4549	0.2943
C2	0.5244	0.4808	0.4066	0.3490
C3	0.0817	0.1352	0.1143	0.2943
C4	0.0689	0.0860	0.0242	0.0624
Total	1	1	1	1

Table 15.
Normalization of Economic Sub-criteria Values

Sub-criteria	C11	C12	C13	C14
C11	0.4637	0.4492	0.4171	0.5527
C12	0.2949	0.2856	0.3518	0.1890
C13	0.1586	0.1158	0.1427	0.1594
C14	0.0829	0.1493	0.0884	0.0988
Total	1	1	1	1

Table 16.
Normalization of Environmental Sub-criteria Values

Sub-criteria	C21	C22	C23
C21	0.1522	0.1671	0.1221
C22	0.5568	0.6113	0.6444
C23	0.2911	0.2216	0.2336
Total	1	1	1

Table 17.
Normalization of Social Sub-criteria Values

Sub-criteria	C31	C32	C33
C31	0.5446	0.6944	0.4934
C32	0.0778	0.0992	0.1645
C33	0.3776	0.2064	0.3421
Total	1	1	1

Table 18.
Normalization of Ethics Sub-criteria Values

Sub-criteria	C41	C42	C43
C41	0.5024	0.6088	0.3869
C42	0.2037	0.2469	0.3869
C43	0.2938	0.1444	0.2262
Total	1	1	1

4.2.3. Weight Matrix

The next stage is to calculate the priority value for each criterion and sub-criteria, by adding up all the normalized values in each row. After that, the sum result is divided by the number of criteria and sub-criteria in each section, so that the priority weight or priority vector is found. The results are shown in the table below.

Table 19.
Priority Weight of Criteria and Sub-criteria Values

Criteria/ Sub-criteria	Priority Vector	Product	HK/PV
Criteria			
C1	34%	1.5229	4.4393
C2	44%	1.8876	4,288
C3	16%	0.6512	4,164
C4	6%	0.2449	4.0572
Sub-criteria			
C11	47%	1.9195	4.0781
C12	28%	1.1357	4.0511
C13	14%	0.588	4.0796
C14	10%	0.4249	4.0518
C21	15%	0.4422	3.0063
C22	60%	1.8287	3.0268
C23	25%	0.7491	3.0117
C31	58%	1.8195	3.1507
C32	11%	0.3447	3.0286
C33	31%	0.9459	3.0641

C41	50%	1.5665	3,137
C42	28%	0.8604	3,082
C43	22%	0.6768	3.0556

4.2.4. Consistency Ratio

Next, the consistency ratio (CR) will be calculated which is the comparison between the consistency index (CI) of a matrix and the consistency index of a random matrix (RI). A CR value <= 0.1 indicates that decision making is constant, but if the value is greater than 0.1 then the pairwise comparison matrix needs to be corrected. The consistency ratio (CR) value can be calculated using the following formula.

$$n = number\ of\ criteria$$

$$multiplication\ result_{i,j} = criteria\ table_{i,j} * priority\ vector_{i,j};\ * is\ matrix\ multiplication$$

$$\lambda_{max} = \frac{\Sigma(\frac{\text{multiplication result}}{\text{priority vector}})}{n} \quad (14)$$

For n=4 then RI=0.9 and for n=3 then RI=0.58 (random index table), then:

$$CR = \frac{CI}{RI} \quad (15)$$

Because CR <= 0.1, it means that the calculation consistency ratio is acceptable and can proceed to the next stage, namely carrying out alternative calculations for each criteria to get priority. The CR calculation results for each criterion and sub-criteria can be seen in the tables below.

Table 20.
Consistency Ratio

	λmaks	n	CI	RI	CR
Criteria	4.2371	4	0.079	0.9	0.0878
Sub-criteria Economy	4.0651	4	0.0217	0.9	0.0241
Sub-criteria Environment	3.0149	3	0.0075	0.58	0.0129
Sub-criteria Social	3.0811	3	0.0406	0.58	0.0699
Sub-criteria Ethics	3.0916	3	0.0458	0.58	0.0789

All CR values in the table above show values less than 0.1. So it can be concluded that decision making is consistent.

4.3. Priotizing Surtainable Subsurface Supplier

After going through the AHP process to determine the priority weights of each criterion and sub-criteria, the next step is to apply the TOPSIS method using the priority weights that have been obtained to determine which suppliers can be prioritized to be selected as subsuface suppliers. The normalization result matrix is listed in the next section.

4.3.1. Normalization Matrix

Normalization matrix is shown in Table 21.

Table 21.
Table of Criteria and Subcriteria for Normalization Results

Alternatives Suppliers	**C1**				**C2**			**C3**			**C4**		
	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43
S1	0.4428	0.4487	0.3935	0.3998	0.6070	0.2394	0.5353	0.6030	0.3990	0.5671	0.4423	0.3086	0.1491
S2	0.5314	0.4188	0.4373	0.4569	0.2601	0.3990	0.3824	0.3015	0.2394	0.3544	0.3686	0.7715	0.4472
S3	0.3542	0.4786	0.4373	0.4341	0.4336	0.3990	0.4588	0.3015	0.5587	0.3544	0.5160	0.4629	0.7454
S4	0.4871	0.4288	0.4810	0.5141	0.4336	0.5587	0.4588	0.6030	0.3990	0.4962	0.5160	-	0.1491
S5	0.3985	0.4587	0.4810	0.4227	0.4336	0.5587	0.3824	0.3015	0.5587	0.4253	0.3686	0.3086	0.4472

The data in this matrix will then be multiplied by their respective priority weights that were obtained in the previous AHP section, thus forming a weighted normalization matrix which is contained in the next section.

4.3.2. Weighted Normalization Matrix

Weighted Normalization Matrix is shown in the Table 22.

Table 22.
Weighted Normalization

Alternatives Suppliers	**C1**				**C2**			**C3**			**C4**		
	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43
S1	0.0521	0.0314	0.0142	0.0105	0.0223	0.0362	0.0333	0.0871	0.0114	0.0438	0.0552	0.0215	0.0083
S2	0.0625	0.0294	0.0158	0.0120	0.0096	0.0603	0.0238	0.0435	0.0068	0.0274	0.0460	0.0538	0.0248
S3	0.0417	0.0335	0.0158	0.0114	0.0159	0.0603	0.0285	0.0435	0.0159	0.0274	0.0644	0.0323	0.0413
S4	0.0573	0.0300	0.0173	0.0135	0.0159	0.0844	0.0285	0.0871	0.0114	0.0383	0.0644	-	0.0083
S5	0.0469	0.0321	0.0173	0.0111	0.0159	0.0844	0.0238	0.0435	0.0159	0.0328	0.0460	0.0215	0.0248
A Max	0.0417	0.0294	0.0142	0.0135	0.0223	0.0844	0.0333	0.0435	0.0159	0.0438	0.0644	-	0.0413
A Min	0.0625	0.0335	0.0173	0.0105	0.0096	0.0362	0.0238	0.0871	0.0068	0.0274	0.0460	0.0538	0.0083

In the table above, the A Max value is the maximum value of the benefit attribute and the minimum value of the cost attribute taken for a positive ideal solution, while A Min is the minimum value of the benefit attribute and the maximum value of the cost attribute taken for a negative ideal solution. Through the A Max and A Min values, a positive and negative square weighted matrix will be formed which will later be used to calculate the distance to alternative solutions. The equation for constructing the positive and negative weighted matrix is as follows

$$S_{+_{ij}} = (A_{Max} - x_{ij})^2 ; S_{-_{ij}} = (x_{ij} - A_{Min})^2 \quad (16)$$

Where S_+ is a positive square weighted matrix and S_- a negative square weighted matrix. The results of these calculations can be seen in the table below.

Table 23.
Positive Squared Weighted Matrix

Alternatives Suppliers	**C1**				**C2**			**C3**			**C4**		
	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43
S1	0.0001	0.0000	-	0.0000	-	0.0023	-	0.0019	0.0000	-	0.0001	0.0005	0.0011
S2	0.0004	-	0.0000	0.0000	0.0002	0.0006	0.0001	-	0.0001	0.0003	0.0003	0.0029	0.0003
S3	-	0.0000	0.0000	0.0000	0.0000	0.0006	0.0000	-	-	0.0003	-	0.0010	-
S4	0.0002	0.0000	0.0000	-	0.0000	-	0.0000	0.0019	0.0000	0.0000	-	-	0.0011
S5	0.0000	0.0000	0.0000	0.0000	0.0000	-	0.0001	-	-	0.0001	0.0003	0.0005	0.0003

Table 24.
Negative Squared Weighted Matrix

Alternatives Suppliers	**C1**				**C2**			**C3**			**C4**		
	C11	C12	C13	C14	C21	C22	C23	C31	C32	C33	C41	C42	C43
S1	0.0001	0.0000	0.0000	-	0.0002	-	0.0001	-	0.0000	0.0003	0.0001	0.0010	-
S2	-	0.0000	0.0000	0.0000	-	0.0006	-	0.0019	-	-	-	-	0.0003
S3	0.0004	-	0.0000	0.0000	0.0000	0.0006	0.0000	0.0019	0.0001	-	0.0003	0.0005	0.0011
S4	0.0000	0.0000	-	0.0000	0.0000	0.0023	0.0000	-	0.0000	0.0001	0.0003	0.0029	-
S5	0.0002	0.0000	-	0.0000	0.0000	0.0023	-	0.0019	0.0001	0.0000	-	0.0010	0.0003

Distance to Alternative Positive and Negative Solutions

The next step, calculate the positive separation measure based on the following formula.

$$D_+ = \sqrt{\sum_{i=1}^{n} \quad S_{+_{ij}}} \qquad (16)$$

$$D_- = \sqrt{\sum_{i=1}^{n} \quad S_{-_{ij}}} \qquad (17)$$

The results obtained are listed in Table 25.

Table 25.
Separation Measure

Distance Alternative Ideal Solution		
Alternatives	D+	D-
S1	0.0775	0.0424
S2	0.0717	0.0526
S3	0.0445	0.0704
S4	0.0579	0.0762
S5	0.0371	0.0770

4.3.3. Sensitivity Analysis

Sensitivity analysis in the AHP-TOPSIS method is an evaluation process of the extent to which changes in the weights or criteria values used in the calculation can affect the final results or alternative rankings. In the sensitivity analysis, the criteria weights will be changed by increasing or decreasing the weight of each sub-criterion by 2% because the smallest criteria weight is 3%, thereby preventing sub-criteria that have a weight below 1% when lowered. The following are the results of the sensitivity analysis.

A. Increase

Increasing the Weight of Quality (C11)

Table 26.
Weight after C11 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	**11,77**	**13,77**
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	5,37

Table 27.
Ranking after C11 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3534	5
S2	0.4215	4
S3	0.6172	2
S4	0.5651	3
S5	0.6776	1

Increasing the Weight of Price (C12)

Table 28.
Weight after C12 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	9,01
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	5,37

Table 29.
Ranking after C12 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3515	5
S2	0.4263	4
S3	0.6123	2
S4	0.5686	3
S5	0.6763	1

Increasing the Weight of Delivery (C13)

Table 30.
Weight after C13 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	5,60
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	5,37

Table 31.
Ranking after C13 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3524	5
S2	0.4258	4
S3	0.6129	2
S4	0.5679	3
S5	0.6755	1

Increasing the Weight of Local Content (C14)

Table 32.
Weight after C14 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	4,62
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	5,37

Table 33.
Ranking after C14 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3510	5
S2	0.4258	4
S3	0.6125	2
S4	0.5689	3
S5	0.6757	1

Increasing the Weight of Eco-design (C21)

Table 34.
Weight after C21 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	5,68
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5%	5%

Table 35.
Ranking after C21 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3665	5
S2	0.4199	4
S3	0.6108	2
S4	0.5675	3
S5	0.6729	1

Increasing the Weight of the Man System. Environment (C22)

Table 36.
Weight after C22 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	17,10
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	5,37

Table 37.
Ranking after C22 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3384	5
S2	0.4291	4
S3	0.6068	2
S4	0.5830	3
S5	0.6893	1

Increasing the Weight of Green Image (C23)

Table 38.
Weight after C23 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	8,22
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	5,37

Table 39.
Ranking after C23 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3561	5
S2	0.4239	4
S3	0.6124	2
S4	0.5682	3
S5	0.6708	1

8. Increasing the weight of the Safety System & Occupational Health (C31)

Table 40.
Weight after C31 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	16,44
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5%	5%

Table 41.
Ranking after C31 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3402	5
S2	0.4506	4
S3	0.6271	2
S4	0.5473	3
S5	0.6875	1

9. Increasing the weight of Corporate Social Responsibility (C32)

Table 42.
Weight after C32 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	4,85
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	5,37

Table 43.
Ranking after C32 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3533	5
S2	0.4216	4
S3	0.6171	2
S4	0.5678	3
S5	0.6798	1

10. Increasing the Weight of Education & Training (C33)

Table 44.
Weight after C33 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	9,72
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	5,37

Table 45.
Ranking after C33 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3622	5
S2	0.4216	4
S3	0.6029	2
S4	0.5694	3
S5	0.6709	1

11. Increasing the Weight of Code of Conduct (C41)

Table 46.
Weight after C41 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	14,48
	C42	6,98	6,81
	C43	5,54	5,37

Table 47.
Ranking after C41 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3529	5
S2	0.4226	4
S3	0.6161	2
S4	0.5712	3
S5	0.6666	1

12. Increasing the Weight of Conflict of Interest (C42)

Table 48.
Weight after C42 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	8,98
	C43	5,54	5,37

Table 49.
Ranking after C42 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3867	5
S2	0.3839	4
S3	0.5818	2
S4	0.6060	3
S5	0.6655	1

13. Increasing the Weight of Transparency in Accounting and Business (C43)

Table 50.
Weight after C43 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,60
	C12	7,01	6,84
	C13	3,60	3,44
	C14	2,62	2,45
C2	C21	3,68	3,51
	C22	15,10	14,94
	C23	6,22	6,05
C3	C31	14,44	14,27
	C32	2,85	2,68
	C33	7,72	7,55
C4	C41	12,48	12,32
	C42	6,98	6,81
	C43	5,54	7,54

Table 51.
Ranking after C43 Increased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3336	5
S2	0.4305	4
S3	0.6352	2
S4	0.5353	3
S5	0.6622	1

B. Decrease

1. Decreasing the Weight of Quality (C11)

Table 52.
Weight after C11 Increased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	9,77
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5,54	5,70

Table 53.
Ranking after C11 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3534	5
S2	0.4215	4
S3	0.6172	2
S4	0.5651	3
S5	0.6776	1

2. Decreasing the Weight of Price (C12)

Table 54.

Weight after C12 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	5,01
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5,54	5,70

Table 55.

Ranking after C12 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3515	5
S2	0.4263	4
S3	0.6123	2
S4	0.5686	3
S5	0.6763	1

3. Decreasing the Weight of Delivery (C13)

Table 56.

Weight after C13 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	1,60
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15

	C43	5,54	5,70

Table 57.
Ranking after C13 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3524	5
S2	0.4258	4
S3	0.6129	2
S4	0.5679	3
S5	0.6755	1

4. Decreasing the Weight of Local Content (C14)

Table 58.
Weight after C14 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	0,62
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5,54	5,70

Table 59.
Ranking after C14 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3510	5
S2	0.4258	4
S3	0.6125	2
S4	0.5689	3
S5	0.6757	1

5. Decreasing the Weight of Eco-design (C21)

Table 60.

Weight after C21 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	1,68
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5%	5%

Table 61.

Ranking after C21 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3665	5
S2	0.4199	4
S3	0.6108	2
S4	0.5675	3
S5	0.6729	1

6. Decreasing the Weight of the Man System. Environment (C22)

Table 62.

Weight after C22 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	13,10
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15

	C43	5,54	5,70

Table 63.
Ranking after C22 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3384	5
S2	0.4291	4
S3	0.6068	2
S4	0.5830	3
S5	0.6893	1

7. Increasing the Weight of Green Image (C23)

Table 64.
Weight after C23 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	4,22
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5,54	5,70

Table 65.
Ranking after C23 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3561	5
S2	0.4239	4
S3	0.6124	2
S4	0.5682	3
S5	0.6708	1

8. Decreasing the weight of the Safety System & Occupational Health (C31)

Table 66.
Weight after C31 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	12,44
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5,54	5,70

Table 67.
Ranking after C31 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3402	5
S2	0.4506	4
S3	0.6271	2
S4	0.5473	3
S5	0.6875	1

9. Decreasing the weight of Corporate Social Responsibility (C32)

Table 68.
Weight after C32 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	0,85
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5,54	5,70

Table 69.
Ranking after C32 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3533	5
S2	0.4216	4
S3	0.6171	2
S4	0.5678	3
S5	0.6798	1

10. Decreasing the Weight of Education & Training (C33)

Table 70.
Weight after C33 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	5,72
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5,54	5,70

Table 71.
Ranking after C33 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3622	5
S2	0.4216	4
S3	0.6029	2
S4	0.5694	3
S5	0.6709	1

11. Decreasing the Weight of Code of Conduct (C41)

Table 72.
Weight after C41 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	10,48
	C42	6,98	7,15
	C43	5,54	5,70

Table 73.
Ranking after C41 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3529	5
S2	0.4226	4
S3	0.6161	2
S4	0.5712	3
S5	0.6666	1

12. Decreasing the Weight of Conflict of Interest (C42)

Table 74.
Weight after C42 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88

C4	C41	12,48	12,65
	C42	6,98	4,98
	C43	5,54	5,70

Table 75.
Ranking after C42 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3867	5
S2	0.3839	4
S3	0.5818	2
S4	0.6060	3
S5	0.6655	1

13. Decreasing the Weight of Transparency in Accounting and Business (C43)

Table 76.
Weight after C43 Decreased

Criteria	Sub-criteria	Weight Before (%)	Weight After (%)
C1	C11	11,77	11,93
	C12	7,01	7,18
	C13	3,60	3,77
	C14	2,62	2,79
C2	C21	3,68	3,84
	C22	15,10	15,27
	C23	6,22	6,39
C3	C31	14,44	14,60
	C32	2,85	3,01
	C33	7,72	7,88
C4	C41	12,48	12,65
	C42	6,98	7,15
	C43	5,54	3,54

Table 77.
Ranking after C43 Decreased

Preference Value		
Alternatives	Preference (V)	Ranking
S1	0.3336	5
S2	0.4305	4
S3	0.6352	2
S4	0.5353	3
S5	0.6622	1

It can be seen in each existing table that even though the weights for each sub-criteria were added or reduced by 2%, the ranking of each alternative subsurface supplier did not change. This shows that the calculation results using AHP-TOPSIS are robust or resistant to data changes. These results indicate that the AHP-TOPSIS method plays a good role as a medium for selecting subsurface suppliers.

Factor sub-criteria has the highest weightage is shown in Figure 3.

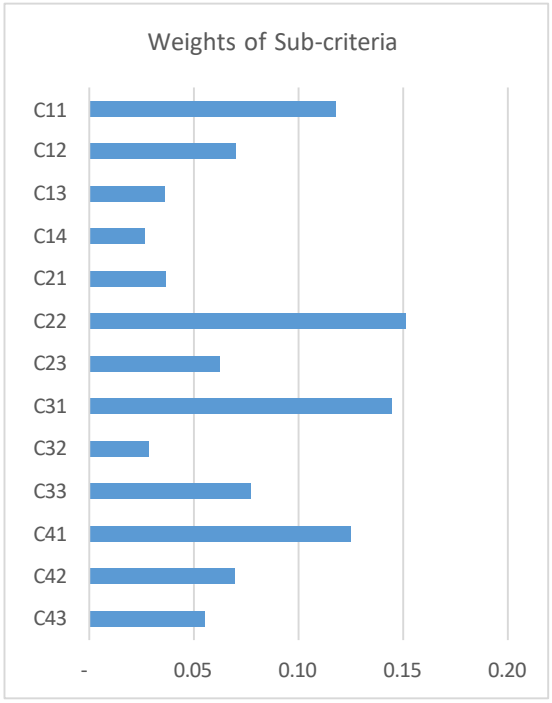

Figure 3.
Weights of Sub-criteria

4.3.4. Analysis of Results

The results of the AHP-TOPSIS method are obtained by calculating the preference value of each supplier which will then be sorted in ranking order from the highest to lowest preference value. The formula for calculating preference values is shown in the following equation.

$$V = \frac{D_{-i}}{D_{+i}+D_{-i}} \qquad (18)$$

The results obtained are shown in Figure 4 and Table 78.

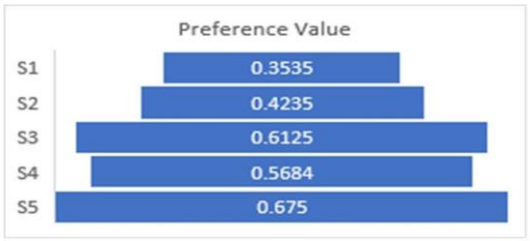

Figure 4.
Preference Value Graph for Alternatives Suppliers

Table 78.
Preference Value and Supplier Ranking

Preference Value (V)		
Alternatives	Preference	Ranking
S1	0.3535	5
S2	0.4235	4
S3	0.6125	2
S4	0.5684	3
S5	**0.6750**	**1**

From the results of calculating the preference value, it was found that supplier S5 had the highest ranking with a preference value of 0,6750 which makes the S5 supplier the main supplier that must be taken into consideration when selecting a subsurface supplier.

III. **Conclusion**

Referring to the findings from the analysis on the Selection of Sustainable Subsurface Suppliers Using the AHP-TOPSIS Method in Upstream Oil and Gas Industry, several conclusions can be drawn, namely from the four criteria factors, the factor with the highest weight that is important in selecting sustainable subsurface suppliers were the environmental factor (44%), Economic (34%), Social (16%), and Ethics (6%). Among the 13 sub-criteria, the highest weights in supplier selection were Environmental Management System (15.10%), Occupational Health & Safety System (14.44%), followed by Code of Conduct (12.48%) and Quality (11.77%). The weighting results were obtained using the AHP method and were declared valid because they had a consistency ratio < 0.1. Then, based on the calculation results of the supplier priority ranking preference values in the TOPSIS analysis, it was found that the alternative supplier S5 has the top ranking with the highest preference value of 0.6750 which makes supplier S5 the main supplier which can be taken into consideration in selecting sustainable subsurface suppliers.

Based on the criteria and sub-criteria are used, in further research it can be further developed by adding other important factors such as flexibility for economic factors, pollution control for environmental factors, and ISO 26000 membership for social factors. Apart from that, in further research you can add experts from the Health Safety and Environment function, you need to pay attention to clear procurement policies and procedures regarding procedures and minimum standards for fulfilling qualifications by suppliers, you can compare research results with other multi-criteria decision making methods such as Fuzzy AHP-TOPSIS, PROMETHEE, ANP, DEMATEL, etc.

1. **Reference**

[1] Akgün, I., & Erdal, H. (2019). Solving an ammunition distribution network design problem using multiobjective mathematical modeling, combined AHP-TOPSIS, and GIS. Computers & Industrial Engineering, 129, 512–528.

[2] Amina, S. R., Deborah, A. T., & Wajdi, M. D. (2022). Analisis Carbon Capture Storage Dari Eksplorasi Migas Dalam Mencapai Sustainable Development Goals. JGE (Jurnal Geofisika Eksplorasi), 8(1), 44–57.

[3] Ayers, J. B., & Odegaard, M. A. (2017). Retail Supply Chain Management, Second Edition. CRC Press.

[4] Çelikbilek, Y., & Tüysüz, F. (2020). An in-depth review of theory of the TOPSIS method: An experimental analysis. Journal of Management Analytics, 7(2), 281–300.

[5] Chai, J., & Ngai, E. W. T. (2019). Decision-making techniques in supplier selection: Recent accomplishments and what lies ahead. Expert Systems with Applications, 140, 112903.

[6] Cinnirella, V., Carpitella, S., Coco, A., Frangiamore, D. D. M., & Geronimo, R. P. (2022). Sustainable suppliers evaluation in the waste management sector: the case of a leading Sicilian enterprise. IFAC PapersOnLine, 55(11), 66–71.

[7] Lavanpriya, C., Muthukumaran, V., & Manoj Kumar, P. (2022). Evaluating Suppliers Using AHP in a Fuzzy Environment and Allocating Order Quantities to Each Supplier in a Supply Chain. Mathematical Problems in Engineering, 2022.

[8] Marzouk, M., & Sabbah, M. (2021). AHP-TOPSIS social sustainability approach for selecting supplier in

construction supply chain. Cleaner Environmental Systems, 2, 100034.

[9] Menon, R. R., & Ravi, V. (2022). Using AHP-TOPSIS methodologies in the selection of sustainable suppliers in an electronics supply chain. Cleaner Materials, 5, 100130.

[10] Ministry of Energy and Mineral Resources of the Republic of Indonesia, Oil and Gas Directorate General (2020). The Strategic Plan

[11] Rahmadani, M., & Suparno (2021). Risk analysis for sustainable supplier selection. Journal of Physics: Conference Series, 1726, 012005.

[12] Rahman, M. M., Bari, A. B. M. M., Ali, S. M., & Taghipour, A. (2022). Sustainable supplier selection in the textile dyeing industry: An integrated multi-criteria decision analytics approach. Resources, Conservation and Recycling Advances, 15, 200117.

[13] Sharma, D., Sridhar, S., & Claudio, D. (2020). Comparison of AHP-TOPSIS and AHP-AHP methods in multi-criteria decision-making problems. Int. J. Industrial and Systems Engineering, 34(2), 203–223.

[14] Sitohang, N. S., Irawan, M. I., Saragi, H. S., Saragih, A., & Simanjuntak, R. (2023). Prioritizing Load Break Switch Placement: Application of Fuzzy AHP-TOPSIS Approaches," 2023 IEEE 3rd International Conference in Power Engineering Applications (ICPEA), Putrajaya, Malaysia, 2023, pp. 32–37,

[15] Sweeney, E., & Waters, D. (2021). Global Logistics: New Directions in Supply Chain Management (8th Ed.). Kogan Page Limited

[16] Taherdoost, H., & Brard, A. (2019). Analyzing the Process of Supplier Selection Criteria and Methods. Procedia Manufacturing, 32, 1024–1034.

[17] Toorajipour, R., Sohrabpour, V., Nazarpour, A., Oghazi, P., & Fischl, M. (2021). Artificial intelligence in supply chain management: A systematic literature review. Journal of Business Research, 122, 502–517.

[18] Utama, D. M. (2021). AHP and TOPSIS Integration for Green Supplier Selection: A Case Study in Indonesia. Journal of Physics: Conference Series, 1845(1).

[19] Wang, C. N., Tsai, H. T., Ho, T. P., Nguyen, V. T., & Huang, Y. F. (2020). Multi-criteria decision making (MCDM) model for supplier evaluation and selection for oil production projects in vietnam. Processes, 8(2).

[20] Wu, C., Lin, Y., & Barnes, D. (2021). An integrated decision-making approach for sustainable supplier selection in the chemical industry. Expert Systems with Applications, 184(May), 115553.

[21] Yazdi, A. K., Wanke, P. F., Hanne, T., Abdi, F., & Sarfaraz, A. H. (2022). Supplier selection in the oil & gas industry: A comprehensive approach for Multi-Criteria Decision Analysis. Socio-Economic Planning Sciences, 79, 101142.