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A Multi-Criteria Decision-Making Methodology for Improving the Supply Chain Management: Aviation Fuels Case Study

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Abstract

A supply chain is a framework that involves everything to originate and sell a product or service. A sustainable supply chain encompasses environmentally and socially sustainable activities on all parts of the chain and bolsters environmental and social standards to reduce greenhouse gas releases and environmental decay. The aviation area is one of the biggest participants in greenhouse gas releases. Today, the world is moving to protect the climate and reduce emissions of harmful fuels. This is why industrial areas, including the aviation area, are searching for sustainable fuels that reduce emissions, preserve the climate, and limit increasing environmental decay. The aim of this study is to pick out the most sustainable substitute aviation fuel via a multi-criteria decision-making (MCDM) based evaluation model. This model combined criteria importance through inter-criteria correlation (CRITIC) and the stable preference ordering towards ideal solution (SPOTIS) methods. The CRITIC method is applied to compute the weights of the criteria. The SPOTIS methodology is applied to rank the substitutes. This study evaluates four substitute aviation fuels against twenty criteria. According to the preferences of six aviation experts, we showed that Algae-fuel is the best and Soybean-fuel is the worst. To demonstrate the suggested method's resilience, we contrast it with alternative approaches. The purpose of the sensitivity analysis was to demonstrate the rank's reliability under various scenarios.

Keywords: Neutrosophic Sets; Decision Making; Aviation Fuels; Supply Chain Management.

1 | Introduction

Increasingly disruptive information and communication technology (ICT) solutions are having a significant impact on supply chains as a result of the digital transformation. The transfer of information, the assistance of performance evaluation, and the promotion of interruption healing are all ways in which these technologies contribute to supply chain resilience (SCR) and green supply chain management. Beyond these domains, ICT has a direct impact on energy consumption, handling of resources, and real-time ecological surveillance [1, 2].

ICT can encourage more eco-friendly business practices by giving companies the ability to assess, monitor, and enhance their environmental performance. ICT may also facilitate stakeholder participation in decision-making, enabling companies to involve employees, customers, communities, and investors while encouraging accountability and trust [3, 4] .

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Supply chain actors are more likely to want to engage if they are encouraged to consume information through the use of information and communication technology (ICT)-based information exchange. The use of information and communication technology (ICT), which improves demand forecasts and lowers costs by optimizing inventories at each level of the supply chain, enables participants in the supply chain to share information in a more dependable and accurate manner[5], [6] .

To set an outline for the upcoming literature review, essential concepts are clarified:

The supply chain incorporates manufacturers , suppliers, transporters, warehouses, retailers, customers and all functions to fulfil a customer request with the goal of achieving compliance with standards of quality, transporting efficiency, and satisfaction for consumers via coordinated systems of parties, procedures, materials, knowledge, and technologies[7], [8].

In recent decades, Organizations are taking greater responsibility for product sustainability and environmental preservation ; Therefore, a term called sustainable supply chain emerged. Sustainability is a theory that seeks to enhance the modality of life of human beings and the earth by ensuring the economic payback of all elements of production[9] . A sustainable supply chain is one that completely incorporates social and ecologically sustainable procedures into a competitive and profitable paradigm[10] .

The energy supply chain can be described as a complex chain of generation, supply, transportation, and maintaining integrated through both physical and financial facilities, exchange of knowledge, and distribution[11] . Global consciousness of ecological problems has grown, particularly as a result of globalization. Therefore, the adverse environmental effect of the products has become increasingly significant.

A sustainable energy supply chain reduces greenhouse gas emissions, increases social fairness, and ensures long-term economic sustainability. Renewable energy provides cleaner alternatives, lowers pollution, and increases the availability of energy, making its implementation critical to meeting global energy transition targets[12], [13]. Sustainability entails retaining an efficient system running, resolving environmental challenges, driving growth in the economy, and fostering social advancement by reducing environmental damage and excessive utilization of nonrenewable resources[9] .

In fact, one of the biggest contentions among governments around the globe is related to issues concerning energy and the environment. Renewable power sources provide a viable and tactical option for accomplishing environmental sustainability, responding effectively to climate change, and meeting the growing need for energy[14], [15]. Renewable energy makes the supply chain economically viable and resilient, which plays a crucial role in the supply chain's ability to disturb demand[16].

It can be said that in the twenty-first century, sustainability has become the essence upon which industries are based and which countries seek to protect the climate. Building an effective supply chain that achieves sustainability in all its stages is an integral part of this essence.

The growing demand for products has led to increased tension in industrial productivity and supply chains, resulting in unfavorable environmental and social consequences[17]. The efficient development of supply chains is now becoming an issue for the deployment of sustainable aviation fuel, a crucial element of the aviation industry's decarbonization[18]. Many efforts have been made recently to promote and develop sustainable aviation fuel extracted from non-fossil materials to reduce the harmful environmental impacts associated with traditional fossil aviation fuel. Reduced carbon fuels are crucial for accomplishing carbon-free evolution in the aviation industry[19].

Aviation occupies a difficult position in the broader picture to resist climate change[20]. Based on data from 2018, the industry contributes to around 2.5% of global carbon dioxide pollution, and 4% of global warming if non-CO_2 contributions are also taken into consideration[21].

Sustainable fuels can deliver a wide range of advantages, containing soil nitrogen supply, storing carbon, water chemical stenography, preservation of biodiversity, and lowering releases of greenhouse gases[22].

The growing trend towards using sustainable sources can notably reduce the carbon intensity of sustainable aviation fuel and increase the possibility of creating clean, carbon-neutral fuel[23]. Sustainable fuel production can generate jobs in the supply chain, benefiting both the economy and communities in rural areas[24].

However expense of sustainable aviation fuels makes this CO2 reduction technique inefficient shortly, there are several reasons in favor of it. The main issue confronting the aviation business is the demand from people and governments to minimize CO2 releases in the aviation area [25].

The modern aviation sector is moving towards overcoming the phenomenon of global warming, reducing the negative impacts on the environment resulting from aviation fuel, and activating carbon-free aviation fuel, which is one of the international environmental goals. Working to develop aviation fuels that are characterized by sustainability is one of the most promising ways to confront this challenge. Because it is characterized as evaluating their relative priorities in a restricted number of possibilities, determining the best sustainable substitute aviation fuel can be seen as a multi-criteria decision-making problem.

Initially, Create a model to assess a group of potential aviation fuel substitutes and determine the optimal one based on a set of attributes. To rank substitute fuels for sustainability, it is required to collect data on their evaluation criteria before using the methods. However, DMs sometimes struggle to assess their sustainability based on certain evaluation criteria[26].

This study's primary contributions are:

- The factors and substitutes are to be assessed by six experts and decision-makers. These professionals have over 20 years of expertise in the fuel and decision-making domains.
- We applied the two MCDM approaches, ranking the substitutes using the SPOTIS technique and computing the criteria weights using the CRITIC technique.
- To deal with uncertainty and conflicting information, the decision makers analyze 20 criteria and four substitutes under the single values neutrosophic numbers.
- The reliability of the rank and strength of the two MCDM techniques is demonstrated by sensitivity and comparison analysis.

The remainder of this research is structured as follows: The literature review is presented in Section 2. The methodology section is shown in Section 3. The results are presented in Section 4. Conclusions are presented in Section 5.

2 | Literature Reviews

There are many environmental impacts, achieving sustainable economic growth, successful technical performance, social benefits, availability, innovation, and the extent of the capacity and organization of the supply chain that must be considered when comparing sustainable types of aviation fuel. The suitability and long-term use of aviation fuel depends on a set of social and economic features, its availability, and its conformity with standards and regulations. Therefore, decision-makers take these elements and features into consideration when making decisions and prefer substitutes to improve supply chain management and enhance sustainability, effectiveness, and commitment to the environment[27].

Abdullah et al.[28] used The PROMETHEE-2 multicriteria methodology in this study to assess SAF manufacturing procedures. Due to the limited data and early stage of SAF technology, a number of aviation industry stakeholders were asked to help gather information and preferences. Eleven (A1 to A11) SAF manufacturing routes were ranked using 24 aspects divided into communal, ecological, commercial, and technical evaluation criteria after stakeholders were actively involved in the research. FUZZY_TOPSIS, FUZZY_VIKOR, and PROMETHEE-II are used to validate data in order to lessen the subjective individual biases of professionals. The optimal feedstock for SAF manufacture, according to the findings, is the direct conversion of CO2 to SAF (A11) in the gasification or Fischer-T synthesis group.

Tillu et al.[29] compared Compressed/liquefied natural gas (CNG/LNG), Vehicles that are hybrids (HV), hydrogen fuel vehicles (HFV), and fully electric vehicles (FEV), and biofuels as the sustainable alternatives to the current fleet of fossil fuel vehicles in this study. Using global weights and the Multi-Criteria Decision-Making (MCDM) technique, alternative solutions are assessed and ranked. To guarantee accurate and uniform results, a cross-validation procedure uses sensitivity analysis, a correlation index method, and six distinct MCDM techniques. A special V-model created with a systems approach is used to illustrate the results. According to the study, FEVs are the best choice for addressing upcoming sustainability issues, followed by HFVs and HEVs.

Mehra et al.[30] suggested a methodical framework for making decisions that makes use of different MCDM schemes in order to find the best renewable diesel generation technology to replace traditional diesel fuel. A total of five production techniques were subjected to a sustainability assessment using fifteen criteria. Using integrated criteria weights relay on (AHP-CRITIC) approaches, ranking systems for various alternatives are calculated using the (MooRA- VikOR-COPrAS) techniques. According to the results, FT diesel is the best substitute, followed by green diesel-I, and feedstock price is the most convincing factor, followed by PM2.5. The robustness of the applied methodologies was compared and checked using qualitative evaluation using the rank reversal test and sensitivity analysis.

Elsayed [31] evaluated and prioritized green fuel options for reducing greenhouse gas emissions in this paper using a multi-criteria-decision-making (MCDM) framework. Four essential criteria are incorporated into the MCDM approach: Technical dependability, cost-efficiency, stability and availability, ecological reliability, and social acceptance are the factors for selection. The weights of these criteria are determined using the removal effects of criteria (MEREC) technique, and the substitutes are ranked using the interactive and multi-criteria-decision-making (TODIM) method, which is an acronym in Portuguese. Triangular Neutrosophic Numbers are used to address the inherent imprecision and confusion associated with the decision-making process. Determining the best options for cutting greenhouse gas emissions is made possible by this integrated method, which offers a thorough assessment of green fuel possibilities.

Borghetti et al.[32] employed an integrated approach that consists of: (i) defining the weights of criteria using the analytical-hierarchy-process(AHP); (ii) using the Elimination-Et-Choix Traduisant-la-REalitè I (ELECTRE I) to identify the most suitable solution among the fuel substitutes; and (iii) refining ranking using an intuitive Weighted Sum Model (WSM). Data was gathered from a panel of experts in Italy using this comprehensive approach. There is discussion of various fuel options with and without support for urban and interurban services.

Markatos DN et al.[33] applied a hybrid model as an evaluation approach. The algorithm produces the final output by combining (AHP) the analytic-hierarchy-process and (WSM) weighted-sum model. The model's sensitivity analysis to data variation influences component ranks, although stays stable across noise levels. The study depended on expert opinions, which introduced subjectivity and bias. It did not take into sustainability considerations or conditions in the real world.

Markatos et al.[34] applied a hybrid model that combines (AHP) the analytic-hierarchy-process and the weighted-sum method. The weighted-sum model is used to combine the pertinent data into a single index that represents a trade-off between technological performance, economic competitiveness, environmental effect, and circularity whereas the analytic hierarchy process is applied to define the weights of the factors under consideration. This research attempted to evaluate and compare the sustainability of various aviation fuels using those variables. The outcomes of the research indicated that the aviation fuels' ranking differed depending on the situations considered, with differing weights allocated to the criterion. The A320 Neo with Sustainable Aviation Fuel (SAF) was commonly cited as the best sustainable one, closely followed by the LH2 aircraft powered by green hydrogen. When compared to the TOPSIS model findings, the results were consistent in most cases, with only a few ranking variations between the two models. This study included a lack of adequate information for some sub-criteria, primarily for the LH2 aircraft, which are currently in development. Furthermore, the study failed to consider social and circular economy issues, which could improve the rating of aircraft sustainability.

Ahmad et al.[35] applied the PROMETHEE II methodology. The technique allows for the evaluation of several substitutes using a variety of criteria, considering expert opinions and rankings via comparisons between pairs. According to economic, social, technical, and environmental impact areas, the evaluation approach yielded rankings of Sustainable Aviation Fuel (SAF) production paths. PROMETHEE II can deal with the uncertainty of expert preferences and rankings, leading to a more powerful decision-making process. The PROMETHEE II method requires comparisons between pairs and sophisticated calculations, which may be difficult to implement without MCDM knowledge.

Ahmad et al.[36] used a Multi-Criteria Decision Analysis (MCDA) as an evaluation method. The work entailed creating a value tree model for assessing sustainable aviation fuel (SAF) manufacturing possibilities. The value tree model assisted in arranging and assigning priority criteria within every stakeholder group included in the SAF supply chain. The research analysis specified thirty-eight performance criteria for seven stakeholder groups. The model utilized the importance index and consensus index metrics to determine the relevance and level of agreement on each criterion. The value tree approach helps stakeholders see and organize complex data, allowing them to make better-informed decisions. The study evaluates SAF manufacturing prospects completely, taking stakeholder preferences into account. Depending on the circumstances and parties engaged in SAF production, the criteria chosen and prioritized will differ.

Sathiyaraj Chinnasamy et al.[37] used (WASPAS) the weighted aggregates sum product assessment system as an evaluation model in this study. In this study, Total Capital Investment, Operating Expenses, min-fuel-selling price per liter, and min-fuel-selling price per megagram were used as evaluation criteria and WASPAS was applied to assess and rank different sustainable aviation fuel production technologies. WASPAS method is used to rank substitutes, DSHC_Pine came first rank and GFT_ Pine came lowest rank.

Alharasees et al. n.d.[38] applied (AHP) analytic-hierarchy-process methodology in this study. The (AHP) methodology helps decision-makers make more informed decisions regarding SAF selection by prioritizing and structuring criteria hierarchically and comparing them pairwise. The criteria for sustainable aviation fuel in this study include environmental impact, societal acceptance, technical viability, and economic viability, as well as the opinions of experts and priorities. The study polled the preferences of only thirteen specialists, which is a tiny sample size, and found no hurdles or problems in choosing the best types of sustainable aviation fuel beyond the parameters listed in the study.

Kaya et al.[39] established an assessment model that combines fuzzy VIKOR and AHP methodologies to evaluate and rank alternatives.

Lee et al.[40] presented a hybrid model that integrates DEMATEL, ANP, and ZOGP methodologies to examine the comprehensive correlations among criteria.

Ren et al. [41] devised an innovative way for identifying alternative energy sources under conditions of insufficient information by amalgamating Dempster-Shafer theory with the trapezoidal fuzzy analytic hierarchy process. Nuclear power is the most sustainable alternative energy source, and the Trapezoidal fuzzy analytic hierarchy process (FAHP) is employed to determine the weights of the criteria. Both methodologies are employed to assess and prioritize alternatives.

Saraswat et al.[42] employed fuzzy-AHP and fuzzy-WASPAS models to create a hierarchical framework of alternatives, criteria, and objectives. They conducted pairwise comparisons to ascertain the relative significance of the criterion and sub-criteria. The WASPAS MCDM methodology was utilized to prioritize the alternatives. Solar energy has been recognized as the most sustainable alternative energy source.

Mukul et al. [43] employed HFL hesitant fuzzy linguistic techniques to evaluate sustainable energy sources. The HFL-AHP method determined the weights of the evaluation criteria, whilst the revised version of HFL-MULTIMOORA was employed to evaluate sustainable energy resources.

Erdogan et al. [44] employed a comprehensive methodology that integrates SWARA (Step-wise Weight Assessment Ratio Analysis) and MULTIMOORA (Multi-Objective Optimization based on Ratio Analysis). The MULTIMOORA technique assessed and ranked the alternatives, identifying VOB20 as the optimal fuel, followed by AFB20 in second place, and VOB5 in last position.

Saraswat et al. [45] designed an integrated method that used FUZZY-ahp (analytical hierarchy process)–FUZZY-TOPsis (a technique for order preference by similarity to ideal solution models. The criteria weights are calculated by using the Fuzzy-AHP approach. The Fuzzy-TOPsis method is used to rank the substitutes. The findings showed that solar energy was selected as the most sustainable energy source, following wind and hydro energy. The limitations were that the study focused only on the major energy options; however, more energy mix options will be considered in future work. There are other methods to obtain criteria weights like PROMETHEE, ELECTRE, and other MCDM methods to rank substitutes.

Çolak et al. [46] devised a comprehensive approach that combines an analytic hierarchy process (AHP) with interval type-2 fuzzy sets to establish a fuzzy multi-criteria decision-making (MCDM) model. The criteria weights were determined by interval type-2 fuzzy AHP, while the hesitant fuzzy TOPSIS approach was employed to assess and rank alternatives. Wind energy was identified as the most sustainable energy source, succeeded by solar and hydraulic energy.

Gudiel Pineda et al. [47] designed an integrated methodology to define the crucial aspects of optimization of the performance of airlines. The research established a comprehensive MCDM model comprising four stages: identifying essential criteria by DRSA, constructing an evaluation framework via DEMATEL, assessing criteria weights utilizing DANP, and grading airline performance employing VIKOR. Results indicated that internal financial aspects carried the most significance (34%), implying that managers have to emphasize financial considerations over operational ones. Table 1 shows the previous studies.

Table 1. Previous studies on the same problem.

Reference	Application	Methodology	Criteria	Number of substitutes	Results
Jaganathan Rajamanickam et al.[27]	Aviation fuels	EDAS	“social benefits, Efficiency, Innovation, Capital cost, Production cost per unit, and GHG emissions	4 substitutes : petroleum refined, Soybean-fuel, and Fischer- Tropsch synthetic from natural gas and Algae -fuel	Fischer-Tropsch synthetic from natural gas was the best substitute, Petroleum refined was the worst substitute, Soybean-fuel was second, Algae-fuel was third.
Farid et al. [48]	Aviation fuels	(AHP) method for q-rung orthopair fuzzy sets (q-ROFSs)	4 main criteria 18 sub-criteria (Economic, Environmental, Social, Market Reliability).	4 substitutes: Natural gas-based, Algal-based, Aviation Gasoline (AVGAS), Soybean based fuel.	Algae-fuel became the first substitute, Soybean-fuel became the worst substitute, Aviation Gasoline was second, Natural gas-based was third.
Chai et al.[26]	Aviation fuels	novel hybrid five-phase fuzzy MCDM approach.	4 main criteria and 14 sub-criteria (Economic criteria, Environmental criteria, Social criteria, Technical criteria).	4 substitutes : petroleum refined, Soybean-fuel, and Fischer-Tropsch synthetic from natural gas and Algae fuel.	Algae-fuel came as the best substitute, and Fischer-Tropsch synthetic from natural gas came as the worst substitute. Soybean -fuel was second, and Petroleum refined was third.

Donyatalab Yaser and Farid [49]	Aviation fuel types-suppliers.	spherical fuzzy linear assignment (SF-LAM) with objective weighting.	4 main criteria and 18 sub-criteria (Economic, Environmental, Social, Market Reliability).	4 substitutes: Aviation Gasoline (AVGAS), Algal, Natural gas-based aviation fuels, Soybean based aviation fuels.	AVAGAS was the best substitute.
Chen et al.[50]	Aviation fuels	fuzzy Analytic Network Process (ANP) and fuzzy Grey Relational Analysis (GRA) techniques	3 main criteria and 10 sub-criteria (Economic, Environmental, And Social criteria).	4 substitutes : petroleum refined, Soybean -fuel, and Fischer- Tropsch synthetic from natural gas and Algae- fuel.	Algae-fuel came as the best substitute, and Fischer-Tropsch synthetic from natural gas came as the worst substitute. Soybean- fuel was second, and petroleum refined was third.
Our study	Aviation fuels	CRITIC method - SPOTIS method	20 criteria (capital cost(f1),production cost(F2),fuel price(f3),operating cost(f4),energy consumption(f5),GHG emissions(f6),water consumption(f7),social acceptability(f8),public acceptance(f9),technology maturity(f10),environmental impact(f11),contrail cirrus(f12),circular economy indicator(f13),fuel intensity(f14),land use(f15),purchase cost(f16),traceability(f17),feedstock sustainability(f18),health impact(f19),biodiversity(F20)).	4 substitutes : petroleum refined(V2), Soybean -fuel(V3), Fischer- Tropsch synthetic from natural gas (V4), and Algae - fuel(V1).	Algae- fuel is the first substitute, soybean- fuel is the worst substitute, petroleum refined is second, Fischer- Tropsch synthetic from natural gas is third.

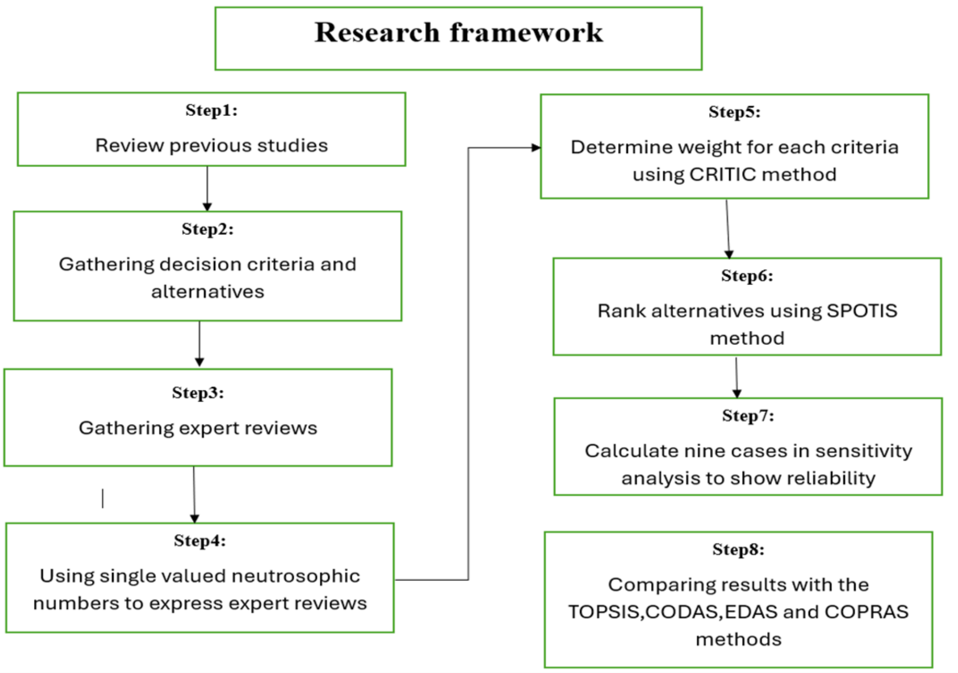

Figure 1. Steps of the proposed method.

3 | Methodology

The study's model combines the CRITIC method and SPOTIS method to evaluate criteria and pick out the most sustainable aviation fuel. This section presents the steps of two methods. Figure one demonstrates every step of the methodology.

This methodology is presented under a Single-Valued Neutrosophic Set to solve the uncertainty issue in the evaluation process. In the first two steps, we review previous studies to know the methods other researchers used and gather the evaluation criteria and substitutes. After collecting experts 'reviews, we turn them into single-valued neutrosophic numbers by using linguistic terms [51]. Then we turn them into crisp values by using the score function:

$$S(x) = \frac{2}{3} + \frac{T_x}{3} - \frac{I_x}{3} - \frac{F_x}{3} \tag{1}$$

3.1 | The Critic Approach

The primary use of the (CRITIC) approach, which was introduced by Diakoulaki, Mavrotas, and Papayannakis in 1995 [52] ,is the computation of feature weight. Each steps of the Critic technique are shown in Figure 2:

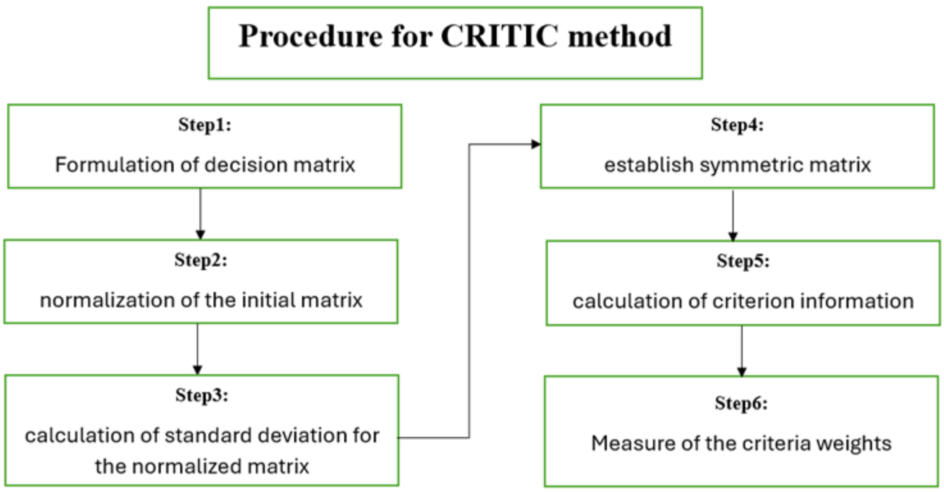

Figure 2. The procedure steps of the Critic methodology

Step1: For a limited collection R consisting of n substitutes and a defined scenario of m assessment criteria c_j, we can formulate the evaluation matrix as follows[53]:

$$Max\ \{c_1(r), c_2(r)\ \ldots., c_m(r)/r\ \epsilon R\ \} \tag{2}$$

Step 2: We can perform normalization of the initial matrix as follows[54]:

$$X_{rj}\ =\ c_j(r)\ -\ c_j\ /\ c_j^*\ -\ c_j^* \tag{3}$$

x_j serves as a function representing membership that maps the values of c_j to the interval [0, 1], c^*_j is an ideal value (best solution), and c_{j^*} is a non-ideal value (worst solution).

Step 3: Determine the normalized matrix's standard deviation.

Step 4: Produce the subsequent A symmetric matrix represents the linear correlation coefficient between the criteria measure of the conflict generated by the criterion.:

$$\sum_{k=1}^{m} (1 - r_{jk}) \tag{4}$$

Step 5: Calculation of criterion information C_j as follows [55]:

$$C_j = \sigma_j \cdot \sum_{k=1}^{m} (1 - r_{jk}) \tag{5}$$

Step 6: Measure the criteria's objective weights as follows [56]:

$$W_j = c_j / \sum_{k=1}^{m} c_k \tag{6}$$

3.2 |SPOTIS Approach

The goal of the SPotis (Stable-Preference-Ordering-Towards-Ideal-Solution) is to tackle problems pertaining to the intricacy of existing multi-criteria decision analysis techniques and their susceptibility to the Rank Reversal problem. This technique makes SPOTIS impervious to this issue by using expert-defined criterion limits to produce a consistent ranking toward an ideal solution [57]. Figure three shows each step of the SPOTIS methodology.

Step 1: Initially, we should ascertain beneficial attributes (max value is preferred) and non-beneficial attributes (min value is preferred).

Step 2: Then we determine the maximum and minimum bounds of criteria.

Step 3: After that, we determine the ideal solution point (b^*_j)which is equal to the maximum bound (b_j^{max})in the case of beneficial criteria and equal to the minimum bound(b_j^{min}) in the case of non-beneficial criteria.

Step 4: Compute the normalized distances to the ideal solution point as follows:

$$r_{ij} = \frac{| x_{ij} - b_j^* |}{| b_j^{max} - b_j^{min} |} \tag{7}$$

Step 5: Calculate weighted normalized distances as follows:

$$P_i = \sum_{j=1}^{m} W_j \cdot r_{ij} \tag{8}$$

Step 6: Finally, the substitute ranks from the smallest value of P_i to the largest value whereas the substitute that has the smallest value of p_i is the best.

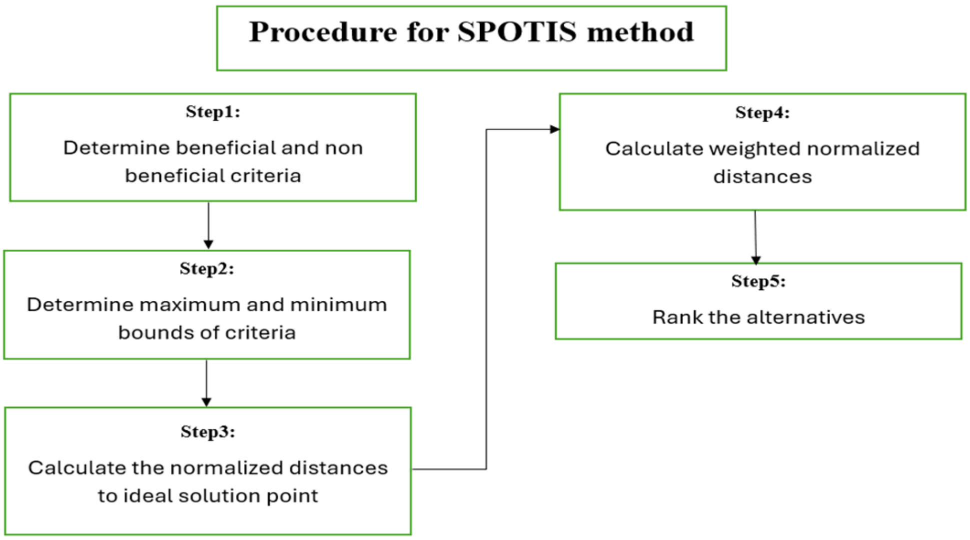

Figure 3. The procedure Steps of the SPOTIS model.

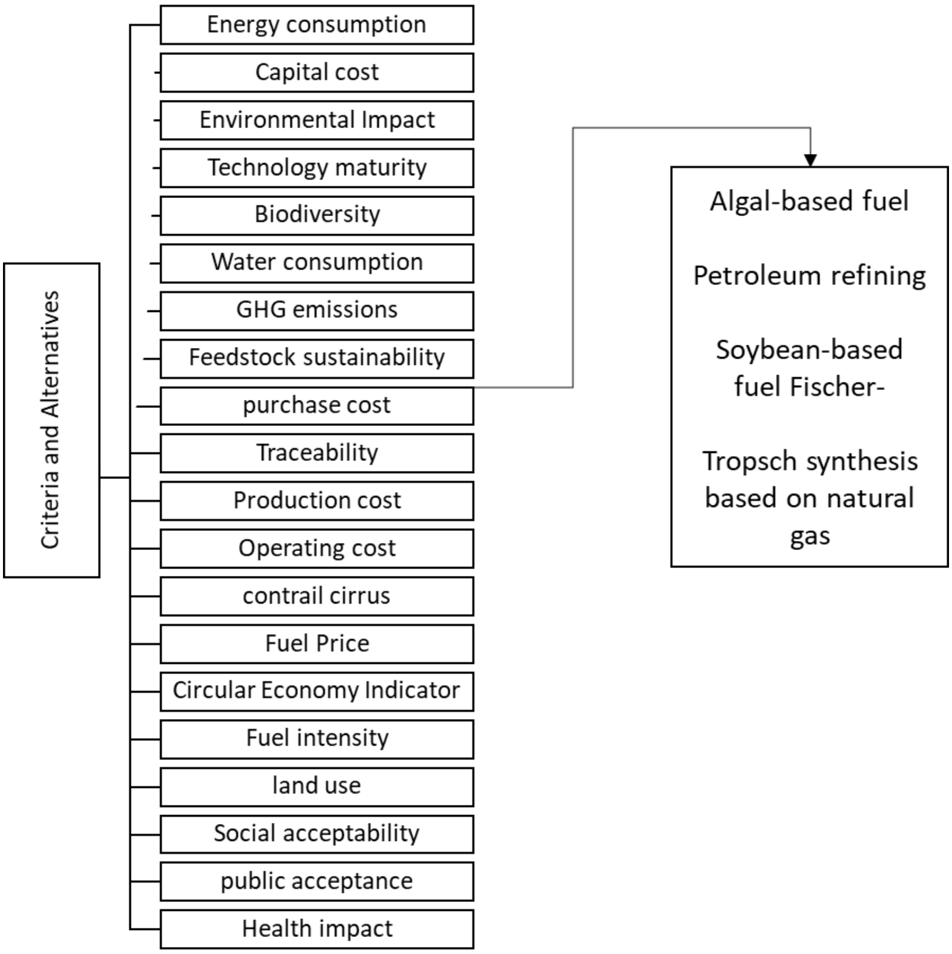

Figure 4. List of criteria and alternatives.

4 | Results and Discussion

4.1 | The Results of the Supposed Framework

We obtain the results from two methods. We gathered 20 criteria and 4 alternatives as shown in Figure 4. six experts and administrators possessing experience in the fuel sector evaluated the criteria and alternatives as presented in Table two.

Table 2. Experts'evaluation matrix.

	P1	**P2**	**P3**	**p4**		**P1**	**p2**	**P3**	**P4**		**P1**	**P2**	**P3**	**P4**
F1	(1,0,0)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	**F1**	(0.65,0.35,0.3)	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(0.05,0.9,0.95)	**F1**	(0.05,0.9,0.95)	(0.8,0.2,0.15)	(1,0,0)	(0.05,0.9,0.95)
F2	(0.9,0.1,0.05)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	**F2**	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(0.9,0.1,0.05)	(0.65,0.35,0.3)	**F2**	(0.35,0.65,0.6)	(0.35,0.65,0.6)	(0.05,0.9,0.95)	(0.35,0.65,0.6)
F3	(1,0,0)	(0.35,0.65,0.6)	(1,0,0)	(0.35,0.65,0.6)	**F3**	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(0.9,0.1,0.05)	**F3**	(0.5,0.5,0.45)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	(0.5,0.5,0.45)
F4	(0.05,0.9,0.95)	(0.35,0.65,0.6)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	**F4**	(0.65,0.35,0.3)	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.9,0.1,0.05)	**F4**	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.5,0.5,0.45)	(0.65,0.35,0.3)
F5	(1,0,0)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	**F5**	(0.9,0.1,0.05)	(0.35,0.65,0.6)	(0.65,0.35,0.3)	(0.35,0.65,0.6)	**F5**	(0.8,0.2,0.15)	(0.8,0.2,0.15)	(0.9,0.1,0.05)	(0.05,0.9,0.95)
F6	(0.9,0.1,0	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	**F6**	(0.9,0.1,0.05	(0.05,0.9,0.95)	(0.9,0.1,0.05)	(0.65,0.35,0.3)	**F6**	(0.65,0.35,0.3)	(0.65,0.35,0.3	(0.8,0.2,0.15)	(0.35,0.65,0.6)

	.05)					)						)		
F7	(1,0,0)	(0.35,0.65,0.6)	(1,0,0)	(0.35,0.65,0.6)	**F7**	(0.35,0.65,0.6)	(1,0,0)	(0.9,0.1,0.05)	(0.9,0.1,0.05)	**F7**	(0.5,0.5,0.45)	(0.05,0.9,0.95)	(0.65,0.35,0.3)	(0.5,0.5,0.45)
F8	(0.05,0.9,0.95)	(0.35,0.65,0.6)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	**F8**	(0.05,0.9,0.95)	(0.65,0.35,0.3)	(0.35,0.65,0.6)	(0.9,0.1,0.05)	**F8**	(0.9,0.1,0.05)	(0.35,0.65,0.6)	(0.05,0.9,0.95)	(0.9,0.1,0.05)
F9	(1,0,0)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	**F9**	(1,0,0)	(0.9,0.1,0.05)	(0.05,0.9,0.95)	(0.35,0.65,0.6)	**F9**	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	(0.05,0.9,0.95)
F10	(0.9,0.1,0.05)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	**F10**	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(0.05,0.9,0.95)	**F10**	(0.35,0.65,0.6)	(0.9,0.1,0.05)	(0.5,0.5,0.45)	(0.35,0.65,0.6)
F11	(1,0,0)	(0.35,0.65,0.6)	(1,0,0)	(0.35,0.65,0.6)	**F11**	(0.8,0.2,0.15)	(0.35,0.65,0.6)	(0.9,0.1,0.05)	(1,0,0)	**F11**	(0.5,0.5,0.45)	(0.8,0.2,0.15)	(0.9,0.1,0.05)	(0.5,0.5,0.45)
F12	(0.05,0.9,0.95)	(0.35,0.65,0.6)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	**F12**	(0.65,0.35,0.3)	(0.05,0.9,0.95)	(0.9,0.1,0.05)	(0.65,0.35,0.3)	**F12**	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(0.05,0.9,0.95)	(0.9,0.1,0.05)
F13	(1,0,0)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	**F13**	(0.9,0.1,0.05)	(1,0,0)	(0.35,0.65,0.6)	(0.9,0.1,0.05)	**F13**	(0.8,0.2,0.15)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	(0.8,0.2,0.15)
F14	(0.9,0.1,0.05)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	**F14**	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.05,0.9,0.95)	(0.9,0.1,0.05)	**F14**	(0.65,0.35,0.3)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.05,0.9,0.95)
F15	(1,0,0)	(0.35,0.65,0.6)	(1,0,0)	(0.35,0.65,0.6)	**F15**	(0.35,0.65,0.6)	(0.8,0.2,0.15)	(1,0,0)	(0.35,0.65,0.6)	**F15**	(0.5,0.5,0.45)	(0.5,0.5,0.45)	(0.9,0.1,0.05)	(0.35,0.65,0.6)
F16	(0.05,0.9,0.95)	(0.35,0.65,0.6)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	**F16**	(0.05,0.9,0.95)	(0.65,0.35,0.3)	(0.9,0.1,0.05)	(0.05,0.9,0.95)	**F16**	(0.5,0.5,0.45)	(0.35,0.65,0.6)	(0.8,0.2,0.15)	(0.5,0.5,0.45)
F17	(1,0,0)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	**F17**	(1,0,0)	(1,0,0)	(0.8,0.2,0.15)	(1,0,0)	**F17**	(0.9,0.1,0.05)	(0.35,0.65,0.6)	(0.65,0.35,0.3)	(0.9,0.1,0.05)
F18	(0.9,0.1,0.05)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	**F18**	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(0.9,0.1,0.05)	**F18**	(0.8,0.2,0.15)	(1,0,0)	(0.5,0.5,0.45)	(0.8,0.2,0.15)
F19	(1,0,0)	(0.35,0.65,0.6)	(1,0,0)	(0.35,0.65,0.6)	**F19**	(0.8,0.2,0.15)	(0.8,0.2,0.15)	(0.9,0.1,0.05)	(0.8,0.2,0.15)	**F19**	(0.65,0.35,0.3)	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.65,0.35,0.3)
F20	(0.05,0.9,0.95)	(0.35,0.65,0.6)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	**F20**	(0.65,0.35,0.3)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	**F20**	(0.5,0.5,0.45)	(1,0,0)	(0.9,0.1,0.05)	(0.5,0.5,0.45)
	P1	P2	P3	P4		P1	P2	P3	P4		P1	P2	P3	P4
F1	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(1,0,0)	(0.05,0.9,0.95)	**F1**	(0.35,0.65,0.6)	(0.35,0.65,0.6)	(1,0,0)	(0.05,0.9,0.95)	**F1**	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)
F2	(0.8,0.2,0.15)	(0.8,0.2,0.15)	(0.35,0.65,0.6)	(0.35,0.65,0.6)	**F2**	(1,0,0)	(0.35,0.65,0.6)	(0.35,0.65,0.6)	(0.35,0.65,0.6)	**F2**	(0.5,0.5,0.45)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.05,0.9,0.95)
F3	(0.5,0.5,0.45)	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.5,0.5,0.45)	**F3**	(0.9,0.1,0.05)	(1,0,0)	(1,0,0)	(0.5,0.5,0.45)	**F3**	(0.35,0.65,0.6)	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)
F4	(1,0,0)	(0.8,0.2,0.15)	(0.8,0.2,0.15)	(0.9,0.1,0.05)	**F4**	(0.8,0.2,0.15)	(0.35,0.65,0.6)	(0.9,0.1,0.05)	(0.35,0.65,0.6)	**F4**	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	(0.5,0.5,0.45)
F5	(1,0,0)	(0.5,0.5,0.45)	(0.5,0.5,0.45)	(0.8,0.2,0.15)	**F5**	(0.65,0.35,0.3)	(1,0,0)	(0.8,0.2,0.15)	(1,0,0)	**F5**	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)
F6	(0.65,0.35	(0.9,0.1,0.05)	(1,0,0)	(0.5,0.5,0.45)	**F6**	(0.5,0.5,0.45	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(0.9,0.1,0.05)	**F6**	(0.5,0.5,0.45)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.05,0.9,0.95)

	,0.3)					)								
F7	(0.9,0.1,0.05)	(0.8,0.2,0.15)	(1,0,0)	(1,0,0)	**F7**	(0.9,0.1,0.05)	(0.8,0.2,0.15)	(0.5,0.5,0.45)	(0.8,0.2,0.15)	**F7**	(0.35,0.65,0.6)	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)
F8	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(1,0,0)	**F8**	(0.9,0.1,0.05)	(0.65,0.35,0.3)	(0.35,0.65,0.6)	(0.65,0.35,0.3)	**F8**	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	(0.5,0.5,0.45)
F9	(0.65,0.35,0.3)	(0.8,0.2,0.15)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	**F9**	(0.65,0.35,0.3)	(0.35,0.65,0.6)	(1,0,0)	(0.5,0.5,0.45)	**F9**	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)
F10	(1,0,0)	(0.5,0.5,0.45)	(0.5,0.5,0.45)	(0.35,0.65,0.6)	**F10**	(1,0,0)	(1,0,0)	(0.9,0.1,0.05)	(0.35,0.65,0.6)	**F10**	(0.5,0.5,0.45)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.05,0.9,0.95)
F11	(0.9,0.1,0.05)	(1,0,0)	(1,0,0)	(0.5,0.5,0.45)	**F11**	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.35,0.65,0.6)	(0.5,0.5,0.45)	**F11**	(0.35,0.65,0.6)	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)
F12	(0.8,0.2,0.15)	(0.9,0.1,0.05)	(1,0,0)	(0.5,0.5,0.45)	**F12**	(0.8,0.2,0.15)	(0.8,0.2,0.15)	(1,0,0)	(0.5,0.5,0.45)	**F12**	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	(0.5,0.5,0.45)
F13	(0.65,0.35,0.3)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.65,0.35,0.3)	**F13**	(0.65,0.35,0.3)	(0.65,0.35,0.3)	(0.9,0.1,0.05)	(0.35,0.65,0.6)	**F13**	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)
F14	(0.9,0.1,0.05)	(0.5,0.5,0.45)	(0.5,0.5,0.45)	(0.8,0.2,0.15)	**F14**	(0.5,0.5,0.45)	(0.35,0.65,0.6)	(0.35,0.65,0.6)	(1,0,0)	**F14**	(0.5,0.5,0.45)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.05,0.9,0.95)
F15	(0.8,0.2,0.15)	(1,0,0)	(0.9,0.1,0.05)	(0.8,0.2,0.15)	**F15**	(0.35,0.65,0.6)	(1,0,0)	(1,0,0)	(0.9,0.1,0.05)	**F15**	(0.35,0.65,0.6)	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)
F16	(0.5,0.5,0.45)	(1,0,0)	(0.8,0.2,0.15)	(0.9,0.1,0.05)	**F16**	(1,0,0)	(0.9,0.1,0.05)	(0.9,0.1,0.05)	(0.8,0.2,0.15)	**F16**	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	(0.5,0.5,0.45)
F17	(1,0,0)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(1,0,0)	**F17**	(0.9,0.1,0.05)	(0.8,0.2,0.15)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	**F17**	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.35,0.65,0.6)
F18	(1,0,0)	(1,0,0)	(1,0,0)	(0.5,0.5,0.45)	**F18**	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.65,0.35,0.3)	(0.5,0.5,0.45)	**F18**	(0.5,0.5,0.45)	(0.8,0.2,0.15)	(0.65,0.35,0.3)	(0.05,0.9,0.95)
F19	(0.65,0.35,0.3)	(0.9,0.1,0.05)	(1,0,0)	(0.65,0.35,0.3)	**F19**	(0.65,0.35,0.3)	(0.5,0.5,0.45)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	**F19**	(0.35,0.65,0.6)	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)
F20	(0.65,0.35,0.3)	(1,0,0)	(0.65,0.35,0.3)	(0.8,0.2,0.15)	**F20**	(0.5,0.5,0.45)	(1,0,0)	(0.9,0.1,0.05)	(0.8,0.2,0.15)	**F20**	(0.05,0.9,0.95)	(0.5,0.5,0.45)	(0.65,0.35,0.3)	(0.5,0.5,0.45)

Step 1: Using Equation (2), we generated the evaluation matrix, which we then aggregated as indicated in Table 3.

Step 2: As indicated in Table 4, the evaluation matrix is normalized using Eq. (3).

Step 3: We calculate the normalized matrix's standard deviation.

Step 4: Using Equation (4), we created a symmetric matrix.

Step 5: We computed the criterion information C_j By using Eq. (5).

Step 6: We measured the objective weights of features by using Eq. (6). Then we applied the SPOTIS methods. From the weights of criteria, we show the production cost has the highest criterion, followed by the capital cost, and fuel cost. We show the water consumption criterion has the lowest weight. Figure four shows the weights of the features.

Table 3. The aggregated evaluation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
V1	0.638889	0.738889	0.65	0.688889	0.588889	0.483334	0.616667	0.708334	0.622223	0.8
V2	0.7	0.641667	0.780556	0.6	0.597223	0.55	0.547223	0.558334	0.6	0.797223
V3	0.838889	0.358334	0.744445	0.7	0.658334	0.738889	0.588889	0.483334	0.652778	0.533334
V4	0.066667	0.441667	0.608334	0.675	0.572223	0.575	0.875	0.605556	0.291667	0.316667
	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
V1	0.741667	0.683334	0.733334	0.675	0.466667	0.372223	0.891667	0.855556	0.691667	0.566667
V2	0.763889	0.608334	0.672223	0.508334	0.727778	0.663889	0.622223	0.825	0.691667	0.944445
V3	0.555556	0.644445	0.558334	0.341667	0.836111	0.8	0.691667	0.672223	0.722223	0.808334
V4	0.597223	0.608334	0.583334	0.688889	0.658334	0.625	0.825	0.558334	0.691667	0.741667

Table 4. The normalization of evaluation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
V1	0	0.758064	0.111112	0.806452	1	0.788135	1	0.915385	1	0
V2	0.255474	0	1	0.709678	0.73913	1	0.333333	0.853846	0.994253	0.255474
V3	1	0.209678	0	0	0	0.872881	0	1	0.448276	1
V4	0.781022	1	0.25	1	0.641304	0	0.54321	0	0	0.781022
	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
V1	0.106666	0	1	0.04	1	1	1	1	1	0
V2	0	1	0.650793	0.52	0.293233	0.318182	0	0.897196	1	1
V3	1	0.51852	0	1	0	0	0.257732	0.383177	0	0.639706
V4	0.8	1	0.142857	0	0.481203	0.409091	0.752577	0	1	0.463236

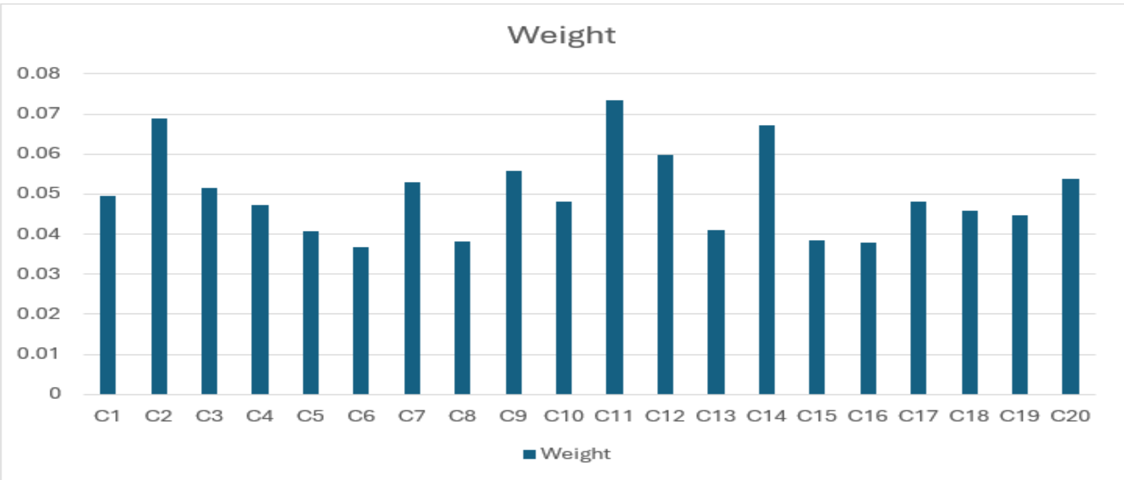

Figure 5. The weight of every factor.

Step 7: We calculated the beneficial attributes and non-beneficial.

Step 8: We determined the maximum and minimum bounds of the criteria.

Step 9: We calculated the ideal solution point (b^*_j) and non-ideal solution.

Step 10: We calculated the normalized distances to the ideal solution by using Eq. (7) as shown in Table 5.

Step 11: We calculated the weighted normalized distances as shown in Table 6.

Step 12: We ranked the alternatives as shown in Figure 6.

After applying the SPOTIS method to rank and determine the most sustainable substitute aviation fuel, we find that algae fuel (V1) is the best substitute then Petroleum refined (V2) followed by Fischer-Tropsch synthetic from natural gas(V4) and Soybean-fuel (V3) is the worst substitute.

Table 5. The normalization of evaluation matrix by SPOTIS.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
V1	0.492752	0.104407	0.737693	0.768254	0.852532	0.654136	0.555953	0.775	0.669445	0.516667
V2	0.553863	0.201629	0.607137	0.857143	0.844198	0.587469	0.625397	0.925	0.691667	0.519445
V3	0.692751	0.484963	0.643249	0.757143	0.783087	0.39858	0.58373	1	0.638889	0.783333
V4	0.079471	0.401629	0.77936	0.782143	0.869198	0.562469	0.297619	0.877778	1	1
	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
V1	0.541162	0.815244	0.825	0.162635	0.55814	0.465278	0.730556	0.702778	0.957692	1
V2	0.518939	0.890244	0.886111	0.329301	0.297029	0.173611	1	0.733334	0.957692	0.622223
V3	0.727273	0.854133	1	0.495968	0.188695	0.0375	0.930556	0.886111	0.927137	0.758333
V4	0.685606	0.890244	0.975	0.148746	0.366473	0.2125	0.797222	1	0.957692	0.825

Table 6. The weighted normalized evaluation matrix by SPOTIS.

	F1	F2	f3	f4	f5	f6	f7	f8	f9	f10
V1	0.024442	0.00718	0.037956	0.036393	0.034664	0.024038	0.029425	0.029513	0.037378	0.02488
V2	0.027474	0.013867	0.031239	0.040604	0.034325	0.021588	0.0331	0.035226	0.038619	0.025014
V3	0.034363	0.033353	0.033097	0.035867	0.03184	0.014647	0.030895	0.038082	0.035672	0.037722
V4	0.003942	0.027622	0.0401	0.037051	0.035342	0.020669	0.015752	0.033427	0.055834	0.048155
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
V1	0.039683	0.048835	0.033918	0.010936	0.021458	0.017625	0.035207	0.032179	0.042778	0.053833
V2	0.038053	0.053328	0.03643	0.022143	0.011419	0.006576	0.048192	0.033578	0.042778	0.033496
V3	0.05333	0.051165	0.041112	0.033351	0.007254	0.00142	0.044846	0.040574	0.041413	0.040823
V4	0.050275	0.053328	0.040084	0.010002	0.014089	0.008049	0.03842	0.045788	0.042778	0.044412

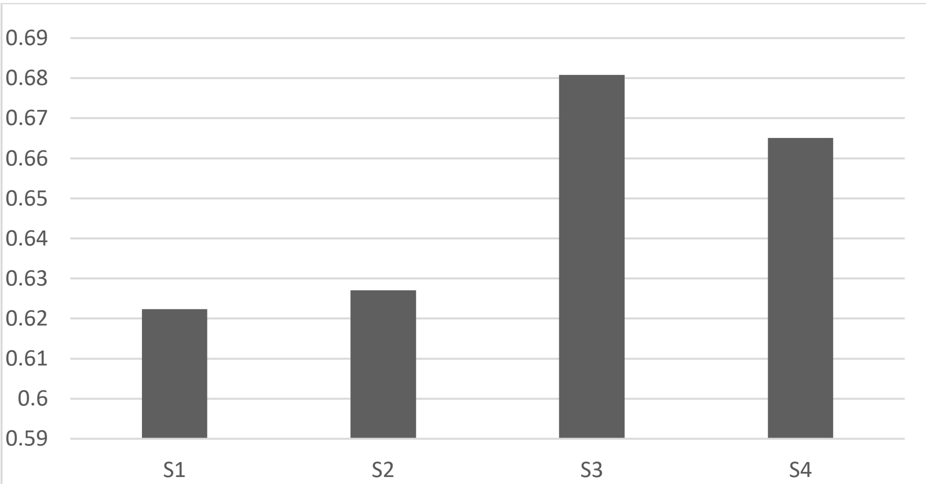

Figure 6. The rank of alternatives.

4.2 | Sensitivity Analysis

To ensure the accuracy and reliability of substitutes' ranks, this paper applies nine cases of sensitivity analysis. In the first case, we put the weight for all criteria equal to 0.05. In the second case, we divide the attributes into beneficial attributes(f8, f9,f10,f13,f17,f18,f20) and non-beneficial attributes (f1,F2,f3,f4,f5,f6,f7,f11,f12,f14,f15,f16,f19) and we assign 50% to beneficial attributes and 50% to non-beneficial attributes. In case 3, we divide the attributes into beneficial attributes (f8,f9,f10,f13,f17,f18,f20) and non-beneficial attributes (f1,f2,f3,f4,f5,f6,f7,f11,f12,f14,f15,f16,f19) and we assign 60% to beneficial attributes and 40% to non-beneficial attributes. In case 4, we divide the attributes to beneficial attributes (f8,f9,f10,f13,f17,f18,f20) and non-beneficial attributes (f1,f2,f3,f4,f5,f6,f7,f11,f12,f14,f15,f16,f19) and we assign 70% to beneficial attributes and 30% to non-beneficial attributes. In case 5, we assign 30% of the weight to (f6,f11) and 70% of the weight for the rest. In case 6, we assign 50% of the weight to (f1,f2,f3,f4,f16) and 50% of the weight for the rest. In case 7, we assign 30% of the weight to (f1,f2,f3,f4,f16) and 30% of the weight for (f6,f11,f12,f14,f19) and 40% for the rest. In case 8, we assign 10% of the weight to (f1,f2,f3,f4,f16) and 50% of the weight for (f6,f11,f12,f14,f19) and 40% for the rest. In case 9, we assign 50% of the weight for (f6,f11,f12,f14,f19) and 50% for the rest.

The results show case2, case3, case4, case8 and case9 determine Algae-fuel is the best substitute aviation fuel and case1, case5, case6 and case7 determine Petroleum refined is the best substitute. Also, the results show case1,case6,case7,case8 and case9 determine Soybean fuel is the worst substitute and case2, case3, case4 and case5 determine Fischer-Tropsch synthetic from natural gas is the worst substitute aviation fuel. Table 7 shows the nine cases.

Table 7. Nine sensitivity analysis cases.

Case number	Rank from best to worst
Case1	$v_2 > v_1 > v_4 > v_3$
Case2	$v_1 > v_2 > v_3 > v_4$
Case3	$v_1 > v_2 > v_3 > v_4$
Case4	$v_1 > v_2 > v_3 > v_4$
Case5	$v_2 > v_1 > v_3 > v_4$
Case6	$v_2 > v_1 > v_1 > v_3$
Case7	$v_2 > v_1 > v_4 > v_3$
Case8	$v_1 > v_2 > v_4 > v_3$
Case9	$v_1 > v_2 > v_4 > v_3$

4.3 | Comparative Analysis

The supposed model is compared with the EDAS,TOPSIS, CODAS, and COPRAS methodologies by using the exact weight resulting from the CRITIC method to show its applicability. The TOPSIS method determines Fischer-Tropsch synthetic from natural gas is the best substitute then Soybean fuel followed by Petroleum refined and Algae-fuel is the worst substitute for sustainable aviation fuel. The CODAS method determines that Soybean-fuel is the best substitute then Algae-fuel followed by Fischer-Tropsch synthetic from natural gas and Petroleum refined is the worst sustainable substitute aviation fuel. The EDAS and COPRAS methods determine that Algae-fuel is the best substitute then Petroleum refined followed by Soybean fuel and Fischer-Tropsch synthetic from natural gas is the worst sustainable substitute for aviation fuel.

4.3.1 | The procedural steps of Technique-for-Order-of-Preference-by Similarity-to-Ideal-Solution model (TOPSIS)

Step 1: we divide the attributes into beneficial attributes(f_8, f_9,f_{10},f_{13},f_{17},f_{18},f_{20}) and non-beneficial attributes (f_1,f_2,f_3,f_4,f_5,f_6,f_7,f_{11},f_{12},f_{14},f_{15},f_{16},f_{19}) and calculate normalized matrix as follows:

$$Z_{ij} = x_{ij} \Big/ \sqrt{\sum_{j=1}^{n} x^2_{ij}} \tag{9}$$

Step 2: We use the following formula to determine the weighted normalized evaluation matrix:

$$V_{ij} = z_{ij} * w_j \tag{10}$$

Step 3: We determine the ideal best and ideal worst values (the ideal best value is the minimum value and the ideal worst value is the maximum value for attributes that are not beneficial, while the ideal best value is the maximum value and the ideal worst value is the minimum value for attributes that are beneficial).

Step 4: we calculate Euclidean distance from the ideal best

$$Ec_i^{+} = [(\sum_{j=1}^{m} v_{ij} - v_j^{+})^2]^{0.5} \tag{11}$$

Step 5: we calculate Euclidean distance from the ideal worst

$$Ec_i^- = [(\sum_{j=1}^{m} v_{ij} - v_j^-)^2]^{0.5} \quad (12)$$

Step 6: we calculate performance score

$$P_i = Ec_i^- / Ec_i^+ + Ec_i^- \quad (13)$$

Table 8. evaluation matrix.

	f1	F2	F3	F4	F5	F6	F7	F8	F9	F10
V1	0.638889	0.738889	0.65	0.688889	0.588889	0.483334	0.616667	0.708334	0.622223	0.8
V2	0.7	0.641667	0.780556	0.6	0.597223	0.55	0.547223	0.558334	0.6	0.797223
V3	0.838889	0.358334	0.744445	0.7	0.658334	0.738889	0.588889	0.483334	0.652778	0.533334
V4	0.066667	0.441667	0.608334	0.675	0.572223	0.575	0.875	0.605556	0.291667	0.316667
weights	0.049604	0.068774	0.051453	0.047371	0.04066	0.036747	0.052926	0.038082	0.055834	0.048155
	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
V1	0.741667	0.683334	0.733334	0.675	0.466667	0.372223	0.891667	0.855556	0.691667	0.566667
V2	0.763889	0.608334	0.672223	0.508334	0.727778	0.663889	0.622223	0.825	0.691667	0.944445
V3	0.555556	0.644445	0.558334	0.341667	0.836111	0.8	0.691667	0.672223	0.722223	0.808334
V4	0.597223	0.608334	0.583334	0.688889	0.658334	0.625	0.825	0.558334	0.691667	0.741667
weights	0.073329	0.059903	0.041112	0.067244	0.038445	0.03788	0.048192	0.045788	0.044668	0.053833

Table 9. normalized evaluation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
V1	0.504086	0.652795	0.464756	0.516316	0.486651	0.406652	0.460642	0.595726	0.554683	0.620867
V2	0.552302	0.566901	0.558105	0.449695	0.493537	0.462742	0.408768	0.469572	0.534873	0.618711
V3	0.661886	0.390204	0.532285	0.524644	0.544039	0.621663	0.439893	0.406496	0.581922	0.413911
V4	0.0526	0.06076	0.434964	0.505906	0.472878	0.483776	0.653614	0.509287	0.260008	0.24576
	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
V1	0.552973	0.536481	0.572345	0.590804	0.340359	0.293359	0.582744	0.579958	0.49445	0.364527
V2	0.569541	0.477599	0.52465	0.444926	0.530797	0.52323	0.40665	0.559246	0.49445	0.607544
V3	0.414212	0.50595	0.435763	0.299049	0.609809	0.630503	0.452035	0.455682	0.516293	0.519986
V4	0.445278	0.477599	0.455274	0.60296	0.480149	0.492581	0.539174	0.378479	0.49445	0.477101

Table 10. Weighted normalized evaluation matrix.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
V1	0.025004	0.044895	0.023913	0.024458	0.019787	0.014943	0.02438	0.022686	0.03097	0.029898
V2	0.027396	0.038988	0.028716	0.021302	0.020067	0.017004	0.021635	0.017882	0.029864	0.029794
V3	0.032832	0.026836	0.027387	0.024853	0.022121	0.022844	0.023282	0.01548	0.032491	0.019932
V4	0.002609	0.004179	0.02238	0.023965	0.019227	0.017777	0.034593	0.019395	0.014517	0.011835
	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
V1	0.040549	0.032137	0.02353	0.039728	0.013085	0.011112	0.028084	0.026555	0.022086	0.019624
V2	0.041764	0.028609	0.021569	0.029919	0.020407	0.01982	0.019597	0.025607	0.022086	0.032706
V3	0.030374	0.030308	0.017915	0.020109	0.023444	0.023883	0.021785	0.020865	0.023062	0.027992
V4	0.032652	0.028609	0.018717	0.040545	0.01846	0.018659	0.025984	0.01733	0.022086	0.025684

Table 11. Positive and negative ideal values.

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
V+	0.002609	0.004179	0.02238	0.021302	0.019227	0.014943	0.021635	0.022686	0.032491	0.029898
v-	0.032832	0.044895	0.028716	0.024853	0.022121	0.022844	0.034593	0.01548	0.014517	0.011835
	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
V+	0.030374	0.028609	0.02353	0.020109	0.013085	0.011112	0.028084	0.026555	0.022086	0.032706
v-	0.041764	0.032137	0.017915	0.040545	0.023444	0.023883	0.019597	0.01733	0.023062	0.019624

Table 12. Distances calculated using Euclidean from ideal _best and ideal _worst values and performance score.

	Ec+	Ec-	Pi	Rank
V1	0.053422	0.036983	0.409084	4
V2	0.048304	0.035387	0.422825	3
V3	0.045708	0.038503	0.457221	2
V4	0.038909	0.053743	0.580053	1

4.3.2 | The procedural Steps of Evaluation Based on Distance-from-Average-Solution (EDAS) Methodology

Step 1: we divide the attributes into beneficial attributes(f_8, f_9,f_{10},f_{13},f_{17},f_{18},f_{20}) and non-beneficial attributes (f_1,f2,f_3,f_4,f_5,f_6,f_7,f_{11},f_{12},f_{14},f_{15},f_{16},f_{19}) and calculate the average solution (AV_j) as follows:

$AV_j =(\sum_{i=1}^{n} X_{ij}) / n$ (14)

Step 2: we calculate Positive Distance from Average (Pod) as follows:

$Pod_{ij} = \max(0,(X_{ij} – AV_j)) / AV_j$ (if jth attribute is beneficial) (15)

$Pod_{ij} = \max(0,(AV_j– X_{ij})) / AV_j$ (if jth attribute is non- beneficial) (16)

Step 3: we calculate weighted sum of Pod_j (positive distance from average values) as follows:

$SP_i = \sum_{j=1}^{m} W_j * Pod_{ij}$ (17)

Step 4:we calculate negative distance from average (Ned) as follows:

$Ned_{ij} = \max(0,(X_{ij} – AV_j)) / AV_j$ (if jth attribute is non-beneficial) (18)

$Ned_{ij} = \max(0,(AV_j– X_{ij})) / AV_j$ (if jth attribute is beneficial) (19)

Step 5: we calculate weighted sum of Ned_j (Negative Distance from Average values) as follows:

$SN_i = \sum_{j=1}^{m} W_j * Ned_{ij}$ (20)

Step 6: we normalize the values of Sp and Sn as follows:

$Zsp_i = Sp_i / \max_i (Sp_i)$ (21)

$Zsn_i = 1 – (Sn_i / \max_i (Sn_i))$ (22)

Step 7: we normalize the values of Zsp and Zsn as follows:

$Nzs_i = 0.5 (Zsp_i + Zsn_i)$ (23)

Table 13. Evaluation matrix and average solution (AV_j).

	F1	F2	F3	F4	F5	F6	F7	F8	F9	F10
V1	0.638889	0.738889	0.65	0.688889	0.588889	0.483334	0.616667	0.708334	0.622223	0.8
V2	0.7	0.641667	0.780556	0.6	0.597223	0.55	0.547223	0.558334	0.6	0.797223
V3	0.838889	0.358334	0.744445	0.7	0.658334	0.738889	0.588889	0.483334	0.652778	0.533334
V4	0.066667	0.441667	0.608334	0.675	0.572223	0.575	0.875	0.605556	0.291667	0.316667
weights	0.049604	0.068774	0.051453	0.047371	0.04066	0.036747	0.052926	0.038082	0.055834	0.048155
AVj	0.561111	0.545139	0.695834	0.665973	0.604167	0.586806	0.656945	0.588889	0.541667	0.611806
	F11	F12	F13	F14	F15	F16	F17	F18	F19	F20
V1	0.741667	0.683334	0.733334	0.675	0.466667	0.372223	0.891667	0.855556	0.691667	0.566667
V2	0.763889	0.608334	0.672223	0.508334	0.727778	0.663889	0.622223	0.825	0.691667	0.944445
V3	0.555556	0.644445	0.558334	0.341667	0.836111	0.8	0.691667	0.672223	0.722223	0.808334
V4	0.597223	0.608334	0.583334	0.688889	0.658334	0.625	0.825	0.558334	0.691667	0.741667
weights	0.073329	0.059903	0.041112	0.067244	0.038445	0.03788	0.048192	0.045788	0.044668	0.053833
AVj	0.664584	0.636111	0.636806	0.553473	0.672223	0.615278	0.757639	0.727778	0.699306	0.765278

Table 14. Positive distance from average (Pod).

	F1	F2	F3	F4	F5	F6	F7	F8	F9	f10
V1	0	0	0.065868	0	0.025287	0.176331	0.061311	0.20283	0.148718	0.307605
V2	0	0	0	0.099061	0.011494	0.062722	0.167019	0	0.107692	0.303065
V3	0	0.342675	0	0	0	0	0.103594	0	0.205128	0
V4	0.881188	0.189809	0.125748	0	0.052874	0.020118	0	0.028302	0	0
	F11	f12	f13	f14	f15	f16	f17	f18	f19	f20
V1	0	0	0.151581	0	0.305785	0.395034	0.176902	0.175572	0.010924	0
V2	0	0.043668	0.055616	0.081556	0	0	0	0.133588	0.010924	0.234119
V3	0.164054	0	0	0.382685	0	0	0	0	0	0.056261
V4	0.101358	0.043668	0	0	0.020661	0	0.088909	0	0.010924	0

Table 15:weighted sum of Pod.

	F1	F2	f3	f4	f5	f6	f7	f8	f9	f10
v1	0	0	0.003389	0	0.001028	0.00648	0.003245	0.007724	0.008304	0.014813
v2	0	0	0	0.004693	0.000467	0.002305	0.00884	0	0.006013	0.014594
v3	0	0.023567	0	0	0	0	0.005483	0	0.011453	0
v4	0.04371	0.013054	0.00647	0	0.00215	0.000739	0	0.001078	0	0
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
v1	0	0	0.006232	0	0.011756	0.014964	0.008525	0.008039	0.000488	0
v2	0	0.002616	0.002286	0.005484	0	0	0	0.006117	0.000488	0.012603
v3	0.01203	0	0	0.025733	0	0	0	0	0	0.003029
v4	0.007433	0.002616	0	0	0.000794	0	0.004285	0	0.000488	0
	SPi									
v1	0.094986									
v2	0.066506									
v3	0.081295									
v4	0.082816									

Table 16. Negative distance from average (Ned).

	F1	f2	f3	f4	f5	f6	f7	f8	f9	f10
v1	0.138614	0.355414	0	0.034411	0	0	0	0	0	0
v2	0.247525	0.17707	0.121756	0	0	0	0	0.051887	0	0
v3	0.495049	0	0.06986	0.051095	0.089655	0.259171	0	0.179245	0	0.128263
v4	0	0	0	0.013556	0	0	0.331924	0	0.461538	0.482406
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
v1	0.115987	0.074236	0	0.219573	0	0	0	0	0	0.259528
v2	0.149425	0	0	0	0.082645	0.079007	0.178735	0	0	0
v3	0	0.0131	0.123228	0	0.243801	0.300226	0.087076	0.076336	0.032771	0
v4	0	0	0.083969	0.244667	0	0.015801	0	0.232824	0	0.030853

Table 17. Weighted sum of Ned.

	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10
v1	0.006876	0.024443	0	0.00163	0	0	0	0	0	0
v2	0.012278	0.012178	0.006265	0	0	0	0	0.001976	0	0
v3	0.024556	0	0.003594	0.00242	0.003645	0.009524	0	0.006826	0	0.006177
v4	0	0	0	0.000642	0	0	0.017568	0	0.02577	0.02323
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
v1	0.008505	0.004447	0	0.014765	0	0	0	0	0	0.013971
v2	0.010957	0	0	0	0.003177	0.002993	0.008614	0	0	0
v3	0	0.000785	0.005066	0	0.009373	0.011372	0.004196	0.003495	0.001464	0
v4	0	0	0.003452	0.016452	0	0.000599	0	0.010661	0	0.001661
	SNi									
v1	0.074637									
v2	0.058437									
v3	0.092495									
v4	0.100034									

Table 18. Normalize the values of NSP and NSN.

	Spi	Sni	zspi	zsni	nzsi	Rank
V1	0.094986	0.074637	1	0.253884	0.626942	1
V2	0.066506	0.058437	0.700165	0.415826	0.557995	2
V3	0.081295	0.092495	0.855858	0.07537	0.465614	3
V4	0.082816	0.100034	0.871874	0	0.435937	4
max	0.094986	0.100034				

4.3.3 | The procedural Steps of CODAS Method (Combinative Distance-based Assessment)

Step 1: we divide the attributes into beneficial attributes(f_8, f_9,f_{10},f_{13},f_{17},f_{18},f_{20}) and non-beneficial attributes (f_1,f_2,f_3,f_4,f_5,f_6,f_7,f_{11},f_{12},f_{14},f_{15},f_{16},f_{19}) and calculate normalized evaluation matrix as follows:

$N_{ij} = X_{ij} / \max X_{ij}$ (if jth attribute is beneficial) (24)

$N_{ij} = \min X_{ij} / X_{ij}$ (if jth attribute is non- beneficial) (25)

Step 2: We compute the matrix containing weighted normalized values as follows:

$r_{ij} = w_j * n_{ij}$ (26)

Step 3: We ascertain values of the negative ideal solution as follows:

$$Ns_j = \min_i r_{ij} \tag{27}$$

Step 4: we ascertain distances of substitutes using Euclidean and Taxicab measures from the negative ideal solution as follows:

$$Ec_i = \sqrt{\sum_{j=1}^{m} (r_{ij} - Ns_j)^2} \tag{28}$$

$$Tx_i = \sum_{j=1}^{m} |r_{ij} - Ns_j| \tag{29}$$

Step 5: we ascertain values of the relative assessment matrix as follows:

$$Ra = [h_{ik}]_{n*n}$$

$$h_{ik} = (Ec_i - Ec_k) + (\psi(Ec_i - Ec_k) * (Tx_i - Tx_k)) \tag{30}$$

Step 6: we ascertain the assessment score and rank the substitutes as follows:

$$Hi = \sum_{k=1}^{n} h_{ik} \tag{31}$$

Table 19:evaluation matrix and max_min values.

	f1	**f2**	**f3**	**f4**	**f5**	**f6**	**f7**	**f8**	**f9**	**f10**
v1	0.638889	0.738889	0.65	0.688889	0.588889	0.483334	0.616667	0.708334	0.622223	0.8
v2	0.7	0.641667	0.780556	0.6	0.597223	0.55	0.547223	0.558334	0.6	0.797223
v3	0.838889	0.358334	0.744445	0.7	0.658334	0.738889	0.588889	0.483334	0.652778	0.533334
v4	0.066667	0.441667	0.608334	0.675	0.572223	0.575	0.875	0.605556	0.291667	0.316667
Weight	0.049604	0.068774	0.051453	0.047371	0.04066	0.036747	0.052926	0.038082	0.055834	0.048155
Max_min	0.066667	0.358334	0.608334	0.6	0.572223	0.483334	0.547223	0.708334	0.652778	0.8
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
v1	0.741667	0.683334	0.733334	0.675	0.466667	0.372223	0.891667	0.855556	0.691667	0.566667
v2	0.763889	0.608334	0.672223	0.508334	0.727778	0.663889	0.622223	0.825	0.691667	0.944445
v3	0.555556	0.644445	0.558334	0.341667	0.836111	0.8	0.691667	0.672223	0.722223	0.808334
v4	0.597223	0.608334	0.583334	0.688889	0.658334	0.625	0.825	0.558334	0.691667	0.741667
Weight	0.073329	0.059903	0.041112	0.067244	0.038445	0.03788	0.048192	0.045788	0.044668	0.053833
Max_min	0.555556	0.608334	0.733334	0.341667	0.466667	0.372223	0.891667	0.855556	0.691667	0.944445

Table 20. Normalized evaluation matrix.

	f1	**f2**	**f3**	**f4**	**f5**	**f6**	**f7**	**f8**	**f9**	**f10**
v1	0.104348	0.484963	0.935897	0.870968	0.971698	1	0.887387	1	0.953192	1
v2	0.095239	0.558442	0.77936	1	0.95814	0.878788	1	0.788235	0.919149	0.996528
v3	0.079471	1	0.817164	0.857143	0.869198	0.654136	0.929245	0.682353	1	0.666667
v4	1	0.811321	1	0.888889	1	0.84058	0.625397	0.854902	0.446809	0.395834
	f11	f12	f13	f14	f15	F16	f17	f18	f19	f20
v1	0.749064	0.890244	1	0.506173	1	1	1	1	1	0.6
v2	0.727273	1	0.916667	0.672131	0.641222	0.56067	0.697819	0.964286	1	1
v3	1	0.943966	0.761364	1	0.55814	0.465278	0.775701	0.785714	0.957692	0.855883
v4	0.930233	1	0.795455	0.495968	0.708861	0.595556	0.925234	0.652598	1	0.785294

Table 21. Weighted normalized evaluation matrix and negative ideal solution points.

	f1	f2	f3	f4	f5	f6	f7	f8	F9	f10
v1	0.005176	0.033353	0.048154	0.041259	0.039509	0.036747	0.046966	0.038082	0.053221	0.048155
v2	0.004724	0.038406	0.0401	0.047371	0.038958	0.032293	0.052926	0.030017	0.05132	0.047988
v3	0.003942	0.068774	0.042045	0.040604	0.035342	0.024038	0.049182	0.025985	0.055834	0.032104
v4	0.049604	0.055798	0.051453	0.042107	0.04066	0.030889	0.0331	0.032556	0.024947	0.019062
Neg.ideal	0.003942	0.033353	0.0401	0.040604	0.035342	0.024038	0.0331	0.025985	0.024947	0.019062
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
v1	0.054928	0.053328	0.041112	0.034037	0.038445	0.03788	0.048192	0.045788	0.044668	0.0323
v2	0.05333	0.059903	0.037686	0.045197	0.024652	0.021238	0.03363	0.044153	0.044668	0.053833
v3	0.073329	0.056546	0.031301	0.067244	0.021458	0.017625	0.037383	0.035977	0.042778	0.046075
v4	0.068213	0.059903	0.032703	0.033351	0.027252	0.022559	0.044589	0.029881	0.044668	0.042275
Neg.ideal	0.05333	0.053328	0.031301	0.033351	0.021458	0.017625	0.03363	0.029881	0.042778	0.0323

Table 22. Euclidean and Taxicab distances.

	Eci	Txi
v1	0.062934	0.191848
v2	0.054894	0.17294
v3	0.066642	0.17811
v4	0.05819	0.156116

Table 23. relative assessment matrix.

	1	2	3	4
1	0	0.008043	-0.00371	0.004747
2	-0.00804	0	-0.01175	-0.0033
3	0.003708	0.01175	0	0.008456
4	-0.00474	0.003296	-0.00845	0

Table 24. The assessment score and the rank.

	Hi	Rank
v1	0.00908	2
v2	-0.02308	4
v3	0.023913	1
v4	-0.00989	3

4.3.4 | The Procedural Steps of Complex Proportional Assessment method (COPRAS)

Step 1: we divide the attributes into beneficial attributes(f_8, f_9,f_{10},f_{13},f_{17},f_{18},f_{20}) and non-beneficial attributes (f_1,f_2,f_3,f_4,f_5,f_6,f_7,f_{11},f_{12},f_{14},f_{15},f_{16},f_{19}) and calculate normalized evaluation matrix as follows:

$$R_{ij} = X_{ij} / \sum_{i=1}^{m} X_{ij} \tag{32}$$

Step 2: we ascertain the weighted normalized evaluation matrix as follows:

$$Y_{ij} = R_{ij} * W_j \tag{33}$$

Step 3: we calculate sum of weighted normalized evaluation matrix as follows:

$$S_{+i} = \sum_{j=1}^{n} Y_{+ij} \quad \text{(for beneficial attributes)} \tag{34}$$

$S_{-i} = \sum_{j=1}^{n} Y_{-ij}$ (for non beneficial attributes) (35)

Step 4: we determine relative significance of substitutes as follows:

$G_i = S_{+i} + (S_{-min} \sum_{i=1}^{m} S_{-i} / S_{-i} \sum_{i=1}^{m} (S_{-min} / s_{-i}))$ (36)

Step 5: we calculate the quantitative utility as follows:

$U_i = [G_i / G_{max}] * 100\%$ (the higher U_i ,the best is the substitute) (37)

Table 25. Evaluation matrix.

	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10
v1	0.638889	0.738889	0.65	0.688889	0.588889	0.483334	0.616667	0.708334	0.622223	0.8
v2	0.7	0.641667	0.780556	0.6	0.597223	0.55	0.547223	0.558334	0.6	0.797223
v3	0.838889	0.358334	0.744445	0.7	0.658334	0.738889	0.588889	0.483334	0.652778	0.533334
v4	0.066667	0.441667	0.608334	0.675	0.572223	0.575	0.875	0.605556	0.291667	0.316667
Weight	0.049604	0.068774	0.051453	0.047371	0.04066	0.036747	0.052926	0.038082	0.055834	0.048155
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
v1	0.741667	0.683334	0.733334	0.675	0.466667	0.372223	0.891667	0.855556	0.691667	0.566667
v2	0.763889	0.608334	0.672223	0.508334	0.727778	0.663889	0.622223	0.825	0.691667	0.944445
v3	0.555556	0.644445	0.558334	0.341667	0.836111	0.8	0.691667	0.672223	0.722223	0.808334
v4	0.597223	0.608334	0.583334	0.688889	0.658334	0.625	0.825	0.558334	0.691667	0.741667
Weight	0.073329	0.059903	0.041112	0.067244	0.038445	0.03788	0.048192	0.045788	0.044668	0.053833

Table 26. Normalized evaluation matrix.

	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10
v1	0.284653	0.338853	0.233533	0.258603	0.243678	0.205917	0.234672	0.300708	0.287179	0.326901
v2	0.311881	0.294267	0.280439	0.225235	0.247126	0.23432	0.208245	0.237028	0.276923	0.325766
v3	0.373762	0.164331	0.267465	0.262774	0.272414	0.314793	0.224101	0.205189	0.301282	0.217934
v4	0.029703	0.202548	0.218563	0.253389	0.236782	0.24497	0.332981	0.257075	0.134615	0.129398
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
v1	0.278997	0.268559	0.287895	0.304893	0.173554	0.151242	0.294225	0.293893	0.247269	0.185118
v2	0.287356	0.239083	0.263904	0.229611	0.270661	0.269752	0.205316	0.283397	0.247269	0.30853
v3	0.208986	0.253275	0.219193	0.154329	0.31095	0.325056	0.228231	0.230916	0.258193	0.264065
v4	0.22466	0.239083	0.229008	0.311167	0.244835	0.25395	0.272227	0.191794	0.247269	0.242287

Table 27. Weighted normalized evaluation matrix.

	f1	f2	f3	f4	f5	f6	f7	f8	f9	f10
v1	0.01412	0.023304	0.012016	0.01225	0.009908	0.007567	0.01242	0.011451	0.016034	0.015742
v2	0.01547	0.020238	0.014429	0.01067	0.010048	0.008611	0.011022	0.009026	0.015462	0.015687
v3	0.01854	0.011302	0.013762	0.012448	0.011076	0.011568	0.011861	0.007814	0.016822	0.010495
v4	0.001473	0.01393	0.011246	0.012003	0.009628	0.009002	0.017623	0.00979	0.007516	0.006231
	f11	f12	f13	f14	f15	f16	f17	f18	f19	f20
v1	0.020459	0.016087	0.011836	0.020502	0.006672	0.005729	0.014179	0.013457	0.011045	0.009965
v2	0.021072	0.014322	0.01085	0.01544	0.010406	0.010218	0.009895	0.012976	0.011045	0.016609
v3	0.015325	0.015172	0.009011	0.010378	0.011955	0.012313	0.010999	0.010573	0.011533	0.014215
v4	0.016474	0.014322	0.009415	0.020924	0.009413	0.00962	0.013119	0.008782	0.011045	0.013043

Table 28. Aggregated results.

	S+i	S-i	S-min /S-i	Gi	Ui	Rank
v1	0.092666	0.17208	0.910638	0.254971	100	1
v2	0.090505	0.17299	0.905849	0.251958	98.81793	2
v3	0.07993	0.167231	0.937042	0.246941	96.8506	3
v4	0.067896	0.156702	1	0.24613	96.53218	4

5 | Managerial Implications

There are some managerial implications in selecting sustainable substitute aviation fuel:

- Petroleum refined is the most suitable in terms of economic aspects, as when the weight of the criteria related to cost and price increases, it becomes the best substitute for aviation fuel.
- Algae fuel is the most suitable in terms of preserving the environment from pollution and reducing emissions and health effects, as when the weight of these criteria increases, it becomes the best substitute for aviation fuel.
- Algae fuel is the most suitable in terms of community acceptance, sustainability of feedstock, and technology aspects, as when the weight of these criteria increases, it becomes the best substitute for aviation fuel.

6 | Conclusion

Industries are increasingly moving towards sustainability of their supply chain. The aviation area must be sustainable because it has a substantial effect on nature. The trend of countries to preserve the environment and reduce pollution has forced airline companies to move towards implementing sustainability in supply chains and setting many standards when choosing types of aviation fuel, as the aviation area is one of the major contributors to environmental degradation. Selecting sustainable substitute aviation fuel is an MCDM issue. This study introduces a framework that combines the CRITIC method to calculate the weights of the selected criteria and the SPOTIS method to rank the substitutes. To ensure accuracy, the study introduces nine cases in sensitivity analysis and compares the results with other MCDM methods. The proposed framework determines that Algae-fuel is the best substitute for aviation fuel. In most cases in sensitivity analysis, algae fuel is the best substitute. In future work, other MCDM methods can be applied to this issue, and we can replace a single-valued neutrosophic framework with another. This study doesn't apply a comparison pairwise method.

Author Contibution

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The authors declare that there is no conflict of interest in the research.

Ethical Approval

This article does not contain any studies with human participants or animals performed by any of the authors

Data Availability

There is no data used in this study.

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