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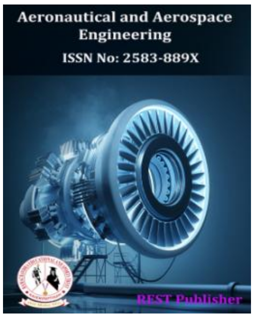

Strategic Assessment of Sustainable Aviation Fuel Production Technologies Using WASPAS Method

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Abstract. *In the last 25 years, the amount of international passenger air traffic has tripled, and it is anticipated that this rapid growth will continue in the upcoming 25 years. Although it has significant economic advantages, the expansion of the aviation sector may also have more negative social and environmental effects. "Sustainable aviation policy" is created as a "balanced plan" to address this. While highlighting the financial advantages of the aviation industry, it seeks to address the significant environmental effects of its expansion. This definition of "sustainable aviation" is contested by other organizations, because there is little consensus among nongovernmental Organizations and the aviation sector. "Standard aviation policy" is therefore in dispute, and several parties attempt to change it to suit their own objectives. In order to build policies for sustainable aviation, competing environmental discourses were identified and examined through a classification exercise assisted by rhetorical, stylistic, and thematic analysis. An approach for making judgments involving multiple attributes, which ensures the consistency requirements of each reciprocal matrix, is the Analytical Hierarchy Process (AHP). Recently, a new method called the Weighted Aggregates Sum Product Assessment System (WASPAS) has been introduced in the literature. WASPAS combines the principles of the weighted product sum and basic aggregate weighting techniques. Linguistic assessments are typically chosen as in decision-making matrix when there is uncertainty and ambiguity. As a result, the purpose of this study is to synthesis WASPAS approaches and adds to the literature. The challenge of outsourcing producer evaluation and selection is resolved using the suggested approach. The options available are HEFA_SO, HEFA_YG, VB_Stover, VB_Pine, ATJ_Stover, ATJ_Pine, DSHC_Stover, DSHC_Pine, FP_Stover, FP_Pine, GFT_Stover, and GFT_Pine. The criteria used for evaluation are TCI (Total Capital Investment in MM$), OPEX (Operating Expenses in MM$), MFSP ($ L− 1) (Minimum Fuel Selling Price in dollars per liter), and MFSP ($ Mg− 1) (Minimum Fuel Selling Price in dollars per mega gram).*

Keywords: *international passenger air traffic, analytical hierarchy process (AHP), Sustainable Aviation, Life Cycle Analysis (LCA), WASPAS.*

1. INTRODUCTION

Aviation fuel consumption and emissions trends that have an impact on the climate are reported by ICAO. These developments take into account the role played by aviation technology, better air traffic control, operational advancements, and SAF deployment. According to ICAO (the International Civil Aviation Organization), the production of sustainable aviation fuels (SAF) has the potential to meet 100% of the aviation industry's demand by the year 2050. This indicates a positive outlook for the future of sustainable aviation, as it could fully replace conventional fossil fuels in the aviation sector, corresponding to a 63% reduction in emissions. Only extremely significant financial investments in the infrastructure needed to produce "sustainable aviation fuels (SAF)" and strong political backing will allow for these levels of fuel production. However, it is unlikely that carbon-neutral growth will be achieved after 2020. Schilling et al. (2016) look at the advantages, difficulties, and emissions brought on by the use of novel technologies and fuels in fleets, including Fischer-Tropsch kerosene, composite wing bodies, all-electric aircraft, strut-braced wings with open rotors, and "non-liquid fuel (liquefied natural gas)". Despite being a relatively recent approach, the "Weighted Aggregate Product Assessment (WASPAS)" has gained significant popularity in the literature since its introduction in 2012. When compared to the "Weighted Sum Model (WSM)" and the Weighted Product Model (WPM), WASPAS is favored due to its ability to provide a more accurate and detailed performance evaluation. It yields a composite solution that is more reliable and dependable, surpassing the simple summation of individual components. Studies in this field often explore various extensions of WASPAS that incorporate fuzzy sets, including human neutrosophic sets, interval-valued hesitant fuzzy sets, and intervals type-2 fuzzy sets. To determine the weights of assessment criteria in Multi-Criteria Decision

Making (MCDM) approaches using pairwise comparisons, the Analytical Hierarchy Process (AHP) method is a widely recognized and utilized technique. On the other hand, the "WASPAS method" is considered a valuable decision-making tool due to its simplicity in quantification and its ability to provide more accurate results compared to other straightforward MCDM methods. This makes WASPAS a preferred choice in many decision-making scenarios. In order to get over WASPAS's lack of criterion weights, the AHP approach is integrated. To solve MCDM issues like location selection, researchers can use a hybrid powertrain of these two techniques to get outcomes that are rational and palatable.

2. SUSTAINABLE AVIATION

The adoption of sustainable aviation fuels (SAF) presents one of the most appealing solutions to significantly reduce CO2 emissions within a relatively short timeframe. To be viable for use in existing aircraft, SAF must closely match the quality and characteristics of conventional jet fuel. This requirement is crucial as it ensures that manufacturers do not need to modify aircraft or engines, and fuel providers and airports do not have to establish new fuel distribution systems. By maintaining compatibility with the current infrastructure, the transition to sustainable aviation fuels becomes smoother and more feasible. The aviation sector has some disadvantages from a technical standpoint for introducing drop-in fuels due to improved homogeneity in current aircraft, engines, and fuel standards. This is the other primary justification for employing these fuels. Using alternative fuels could be another way to lessen aviation's carbon footprint. A synthesis of different biofuels generated from plant-based resources, "sustainable aviation fuel (SAF)" is a fuel that is carbon-neutral. Due to their potential to lower greenhouse gas emissions, biofuels are a prospective replacement for petroleum fuels, which are currently utilised in commercial aircraft. Some SAFs made from fats, oils, agricultural waste, and improper waste management are legal in India. The effects of SAF manufacturing on the environment have been the subject of several researches. In the latest Life Cycle Analysis (LCA) study, the focus was on two vital criteria: reducing greenhouse gas (GHG) emissions and enhancing energy efficiency. The study revealed that certain sustainable aviation fuel (SAF) conversion processes require more energy compared to utilizing waste and leftover materials as feedstock. Specifically, in a research conducted by Staples et al. in 2018, they examined emission reductions achieved through SAF production using non-food feed stocks across all stages of the products' life cycles and various conversion methods. This research aimed to assess the environmental impact and efficiency of SAF production from different sources to guide decision-making in the aviation industry's sustainable fuel initiatives. According to the research; it will take about $12 billion in investments annually to reduce GHG emissions to 50% or less by 2050. Other studies have looked at a constituent and process evaluation in addition to various feedstocks and conversion methods. Ganguli et al. (2018) conducted an LCA research on a lumber feed for SAF production. The research findings indicate that the production of sustainable aviation fuel (SAF) has the potential to reduce global warming effects significantly when compared to traditional jet fuel. Specifically, the study revealed that the manufacture of SAF could lead to a reduction in global warming impact by as much as 78%. This highlights the substantial environmental benefits of adopting SAF as a viable alternative to conventional jet fuel, contributing to efforts in mitigating climate change and promoting sustainable aviation practices. Similarly, Fortier et al. assessed the HTL of microalgae feedstock. There are two different manufacturing plants. According to their investigation, fuel generated in a traditional refinery has a higher concentration of GHGs than SAF manufactured in a sewerage system. Furthermore, Seber et al. (2014) performed LCA to assess Energy and greenhouse savings and manufacturing cost linked with HEFA jet form yellow and fat. Comparing LCA of SAF made from yellow grease to petroleum-based jet fuel, the former produced reduced GHG emissions. In addition to its positive impact on reducing greenhouse gas (GHG) emissions, SAF derived from yellow gasoline as a feedstock presents the advantage of having a lower minimum selling price (MSP) compared to other SAF production methods. It is important to note that Life Cycle Analysis (LCA) studies have consistently demonstrated the potential of sustainable aviation fuels to decrease GHG emissions in the aviation sector. However, it's essential to consider that LCA studies can vary in their findings due to the complex and dynamic nature of the environment and the aviation industry. Each LCA report may make its own unique assumptions and establish specific system boundaries, which can lead to variations in their results. Therefore, when comparing LCA research on sustainable aviation fuels, one should be cautious about drawing direct conclusions, as each study's specific assumptions and limitations can significantly influence the outcomes. Instead, a broader understanding of the collective findings can help inform decision-making and policy development in promoting sustainable aviation practices. Sgouridis et al. utilized a continuous-time simulation approach as the foundation of their research to assess the effect of short-term policies and initiatives aimed at reducing CO2 emissions in the global aviation sector. These simulation approaches allowed them to model and analyze the potential impact of various interventions and measures on achieving the goal of eliminating or significantly reducing carbon dioxide emissions from the aviation industry. By using this method, they were able to simulate different scenarios and evaluate the effectiveness of different strategies in tackling the environmental challenges posed by aviation-related emissions. According to the report, utilising poor fuels and an emissions reductions mechanism together could help achieve the goal of lowering emissions.

3. WASPAS METHOD

In our study, we applied the Multi-Criteria Decision Making (MCDM) framework to develop and validate a set of high-level parameters used to evaluate compressed aerial photographs. The MCDM approach allowed us to systematically analyze and prioritize these parameters based on their significance in assessing the quality and effectiveness of compressed aerial photographs. Through the verification process, we ensured that the selected parameters were reliable and relevant for accurately evaluating and comparing compressed aerial imagery, providing valuable insights for various applications and decision-making processes in the field of aerial photography. In order to estimate lossy compression techniques that are controlled by suitable quality parameters for data compression and graphically acceptable lossy compression, we have created a new MCDM issue. Furthermore, we conducted a ranking of loss compression methods at different compression ratios based on their performance with various aerial image resolutions. To ensure the consistency and reliability of the MCDM ranking results, we adopted both the Direct Weighted Determination and the "Weighted Aggregate Product Assessment (WASPAS)" procedures in a neutrosopic environment. These approaches have shown exceptional stability when applied to address a wide range of real-world challenges. As a result, we have developed an innovative multi-criteria decision-making process that facilitates the selection of the most suitable lossy compression method for aerial photographs. Which also includes approaches for resolving other subtasks like adjusting weights or feature sets. There are five parts to the article. Gives a summary of studies that have been published on evaluating the quality of compressed aerial images. specifies the direct weights and MCDM pythagorean fuzzy WASPAS methodologies for data processing, as well as the overall structure of the strategy, a set of alternatives, and conditions for the non - linear and non-task of evaluation criteria of loss decompression of aerial photographs. A selection of aerial photos is offered together with a quality evaluation, a ranking of the collection's summary results through using Neutrosopic WASPAS-SVNS method, or a presentation of the study. There are conclusions and recommendations for the future. The main objective of this study is to propose a novel strategy that brings together the improved accuracy of non-linear and non-decision making methods along with the robustness of interval-valued fuzzy numbers in effectively dealing with uncertainty. By combining these different approaches, the proposed strategy aims to address complex problems where uncertainty is a critical factor, providing a more comprehensive and reliable solution that surpasses the limitations of traditional linear decision-making methods. In light of this, a proposed extension of the recently created "Weighted Aggregate Product Assessment (WASPAS)" is made. To obtain the best estimation accuracy, WASPAS employs a suggested strategy to optimise the weighted aggregate function. By choosing an appropriate location, it has been effectively applied to the sustainable and environment evaluation of modernising multiple residential homes. In a practical case study, the ranking of facades for both public and commercial buildings was carried out, and the reliability of the method was successfully validated. To enhance the accuracy of rankings, particularly in critical situations, the Weighted Aggregate Product Assessment System (WASPAS) was employed. Specifically, the WASPAS method was utilized to select the most suitable occupational safety approach during construction work. This application demonstrated how incorporating the WASPAS approach can improve decision-making precision in essential scenarios, ensuring the best safety measures are implemented during the construction process. This approach, known as WASPAS-IVIF in the current study, is expanded with intermission intuitionistic fuzzy numbers. A general version of fuzzy sets that takes into account both the ordinal membership degree and the non-membership degree of the fuzzy numbers are interval-valued intuitionistic fuzzy numbers. The experts were given a questionnaire to complete in order to determine the weight efficiency indices. SWARA-WASPAS was established in response to their input. With regard to SWARA evaluation, weighting criteria, and key supplier selection, WASPAS is utilised to assess various options. Since the "SWARA method" is correlated with the ability of trying to assess the conclusions or special interests about the great significance of qualities in the taken into account when designing (Kersuliene et al.., 2010), Aghdaie et al. (2013) asserted that the rationalisation there next to using this approach is to use the expertise and insights of experts. The first parameter in the ranking is thought to be the most significant, and the final parameter in the ranking is thought to be the least significant, according to experts who apply their own instincts. The SWARA approach is more appealing and effective for researchers due to the fact that it requires fewer comparison than other MCDM techniques, according to Stanujkic et al (2015).'s comparison of Contact with different with other MCDM methods like AHP, ANP, etc. The WASPAS method was introduced by Javadskas et al. in 2012, and their analysis demonstrated that it outperforms other approaches in terms of accuracy and robustness. This method combines two well-known Multi-Criteria Decision Making (MCDM) techniques, the "weighted sum method (WSM)" and the "weighted product method" (WPM). The study revealed that by utilizing both WSM and WPM together, the results obtained are more accurate compared to using either method individually. Despite being relatively new tools, the SWARA (Step-wise Weight Assessment Ratio Analysis) and WASPAS methods are gaining recognition in modern research due to their effectiveness in tackling complex decision-making problems. Researchers and practitioners are increasingly adopting these methods to address various real-world challenges, further establishing their reputation as valuable tools in the field of decision-making and analysis.

4. RESULT AND DISCUSSION

TABLE 1. Sustainable Aviation

	TCI, MM$	OPEX, MM$	MFSP, $ L− 1	MFSP, $ Mg− 1
HEFA_SO	77.00000	54.00000	1.12000	1446.00000
HEFA_YG	69.00000	46.00000	0.88000	1190.00000
VB_Stover	398.00000	89.00000	2.32000	2610.00000
VB_Pine	425.00000	99.00000	2.54000	2796.00000
ATJ_Stover	417.00000	86.00000	2.31000	2793.00000
ATJ_Pine	435.00000	90.00000	2.42000	2862.00000
DSHC_Stover	654.00000	136.00000	3.61000	4689.00000
DSHC_Pine	677.00000	146.00000	3.86000	4967.00000
FP_Stover	257.00000	74.00000	1.78000	1963.00000
FP_Pine	249.00000	69.00000	1.68000	1751.00000
GFT_Stover	342.00000	73.00000	1.94000	2146.00000
GFT_Pine	254.00000	108.00000	2.79000	2968.00000

The evaluation parameters TCI (Total Capital Investment in MM$), OPEX (Operating Expenses in MM$), MFSP ($ L− 1) (Minimum Fuel Selling Price in dollars per liter), and MFSP ($ Mg− 1) (Minimum Fuel Selling Price in dollars per megagram) are provided for each alternative. The Final Value will be calculated using the MOORA (Multi-Objective Optimization on the basis of Ratio Analysis) method to rank the alternatives based on their sustainability for aviation.

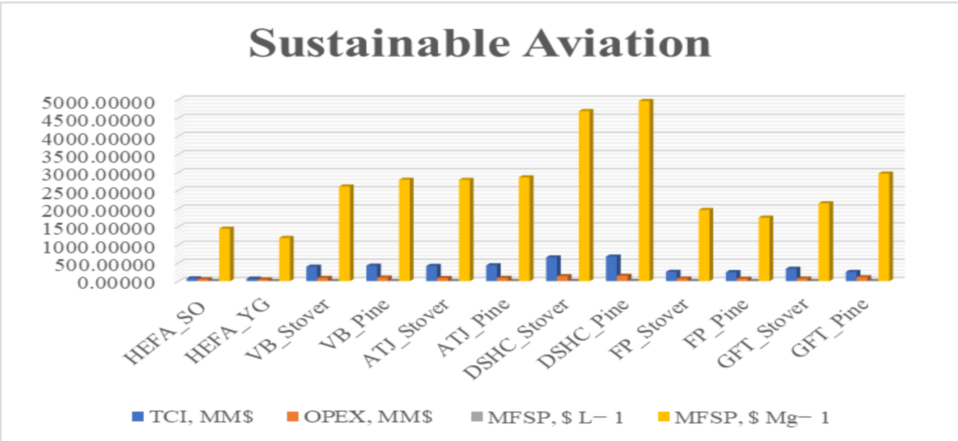

FIGURE 1. Sustainable Aviation

The figure would likely be a bar chart or a radar chart, where each alternative (HEFA_SO, HEFA_YG, VB_Stover, VB_Pine, ATJ_Stover, ATJ_Pine, DSHC_Stover, DSHC_Pine, FP_Stover, FP_Pine, GFT_Stover, and GFT_Pine) is represented along the x-axis. The y-axis could represent the Final Value calculated using the MOORA method. The bars or data points on the chart would indicate the Final Value of each alternative.

TABLE 2. Performance value

HEFA_SO	0.11374	0.36986	0.78571	0.82296
HEFA_YG	0.10192	0.31507	1.00000	1.00000
VB_Stover	0.58789	0.60959	0.37931	0.45594
VB_Pine	0.62777	0.67808	0.34646	0.42561
ATJ_Stover	0.61595	0.58904	0.38095	0.42607
ATJ_Pine	0.64254	0.61644	0.36364	0.41579
DSHC_Stover	0.96603	0.93151	0.24377	0.25379
DSHC_Pine	1.00000	1.00000	0.22798	0.23958
FP_Stover	0.37962	0.50685	0.49438	0.60621
FP_Pine	0.36780	0.47260	0.52381	0.67961
GFT_Stover	0.50517	0.50000	0.45361	0.55452
GFT_Pine	0.37518	0.73973	0.31541	0.40094

Shows the table 2 Performance value is divided by the maximum of the given value

TABLE 3. Weight

	Weight			
HEFA_SO	0.25	0.25	0.25	0.25
HEFA_YG	0.25	0.25	0.25	0.25
VB_Stover	0.25	0.25	0.25	0.25
VB_Pine	0.25	0.25	0.25	0.25
ATJ_Stover	0.25	0.25	0.25	0.25
ATJ_Pine	0.25	0.25	0.25	0.25
DSHC_Stover	0.25	0.25	0.25	0.25
DSHC_Pine	0.25	0.25	0.25	0.25
FP_Stover	0.25	0.25	0.25	0.25
FP_Pine	0.25	0.25	0.25	0.25
GFT_Stover	0.25	0.25	0.25	0.25
GFT_Pine	0.25	0.25	0.25	0.25

Table 3 shows the weight of the Sustainable Aviation the weight is equal for all the value in the set of data in the table 1. The weight is multiplied with the previous table to get the next value.

Table 4. Weighted normalized decision matrix (WSM) and Preference Score

	Weighted normalized decision matrix				Preference Score
HEFA_SO	0.02843	0.09247	0.19643	0.20574	0.52307
HEFA_YG	0.02548	0.07877	0.25000	0.25000	0.60425
VB_Stover	0.14697	0.15240	0.09483	0.11398	0.50818
VB_Pine	0.15694	0.16952	0.08661	0.10640	0.51948
ATJ_Stover	0.15399	0.14726	0.09524	0.10652	0.50300
ATJ_Pine	0.16064	0.15411	0.09091	0.10395	0.50960
DSHC_Stover	0.24151	0.23288	0.06094	0.06345	0.59877
DSHC_Pine	0.25000	0.25000	0.05699	0.05990	0.61689
FP_Stover	0.09490	0.12671	0.12360	0.15155	0.49677
FP_Pine	0.09195	0.11815	0.13095	0.16990	0.51096
GFT_Stover	0.12629	0.12500	0.11340	0.13863	0.50332
GFT_Pine	0.09380	0.18493	0.07885	0.10024	0.45782

Table 4 presents the weighted normalization decision matrix obtained through the Weighted Sum Method (WSM). This matrix is derived by multiplying the weights (from Table 2) with the corresponding performance values (from Table 3) for each evaluation parameter. The resulting values are then entered into the respective cells of Table 4. The Preference Score for the WSM is calculated by summing up the values in each row of the weighted normalization decision matrix. This Preference Score represents the overall performance of each alternative concerning the evaluation parameters, considering their respective weights. Essentially, it reflects the aggregated desirability of each alternative based on the WSM approach. A higher Preference Score indicates a more favorable alternative in the context of the WSM.

TABLE 6. Weighted normalized decision matrix (WPM) and Preference Score

	Weighted normalized decision matrix				Preference Score
HEFA_SO	0.58073	0.77985	0.94149	0.95246	0.40611
HEFA_YG	0.56502	0.74921	1.00000	1.00000	0.42332
VB_Stover	0.87564	0.88361	0.78478	0.82173	0.49895
VB_Pine	0.89012	0.90745	0.76721	0.80770	0.50054
ATJ_Stover	0.88590	0.87607	0.78563	0.80792	0.49262
ATJ_Pine	0.89531	0.88608	0.77655	0.80301	0.49469
DSHC_Stover	0.99140	0.98242	0.70266	0.70977	0.48574
DSHC_Pine	1.00000	1.00000	0.69099	0.69962	0.48343
FP_Stover	0.78494	0.84376	0.83852	0.88238	0.49004
FP_Pine	0.77876	0.82913	0.85073	0.90796	0.49875
GFT_Stover	0.84306	0.84090	0.82067	0.86294	0.50206
GFT_Pine	0.78264	0.92740	0.74941	0.79574	0.43283

Table 4 displays the weighted normalization decision matrix obtained using the Weighted Product Method (WPM). This matrix is computed by multiplying the weights (from Table 2) with the corresponding performance values (from Table 3) for each evaluation parameter. The resulting values are entered into the respective cells of Table 4. The Preference Score for the Weighted Product Model (WPM) is calculated by taking the product of the values in each row of the weighted normalization decision matrix. This Preference Score represents the overall desirability of each alternative based on the WPM approach. By multiplying the individual values in each row, the WPM captures the combined influence of each evaluation parameter, providing a holistic assessment of the alternatives. Higher Preference Scores indicate more favorable alternatives according to the WPM.

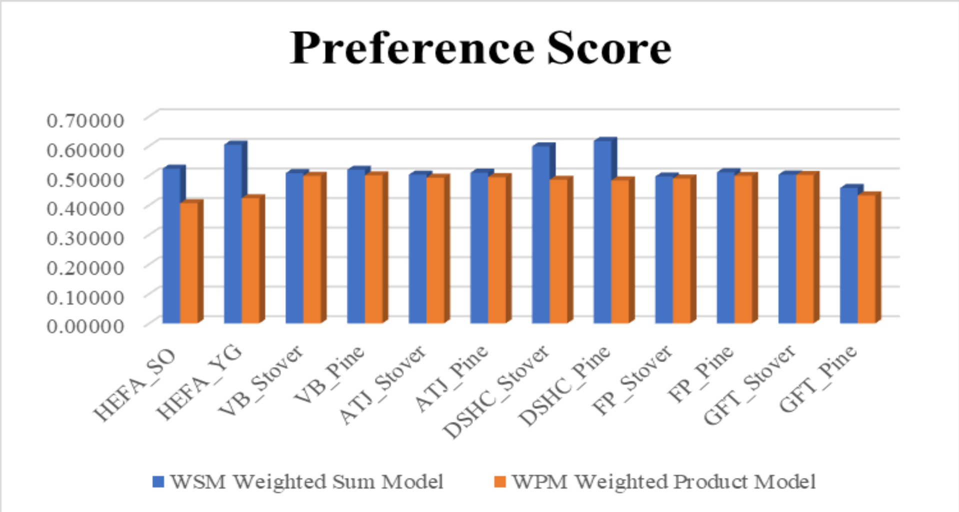

FIGURE 2. Preference Score

The figure would likely be a bar chart, where each alternative (including HEFA_YG) is represented along the x-axis. The y-axis could represent the Preference Score calculated for each alternative. For each alternative, there would be two bars side by side, one corresponding to the Preference Score obtained using the Weighted Sum Model (WSM) and the other corresponding to the Preference Score obtained using the Weighted Product Model (WPM). The heights of the bars would represent the respective Preference Scores. The figure would illustrate how the Preference Scores differ between the two models (WSM and WPM) for each alternative, allowing for a visual comparison of the ranking results. The alternative with the highest Preference Score in the WSM and WPM would be indicated by the tallest bar on the chart, representing the most preferred choice based on both models.

TABLE 7. WASPAS coefficient and Rank

	lambda	WASPAS Coefficient	Rank
HEFA_SO		0.46459	11
HEFA_YG		0.51378	3
VB_Stover		0.50357	6
VB_Pine		0.51001	4
ATJ_Stover		0.49781	9
ATJ_Pine		0.50215	8
DSHC_Stover		0.54226	2
DSHC_Pine		0.55016	1
FP_Stover		0.49340	10
FP_Pine		0.50485	5
GFT_Stover		0.50269	7
GFT_Pine	0.5	0.44532	12

Table 7 shows the WASPAS Coefficient value lambda 0.5 and sustainable aviation ranking values.the WASPAS coefficient value DSHC_Pine the highest value and GFT_Pine is lowest value. DSHC_Pine is got first rank and GFT_Pine is got lowest rank

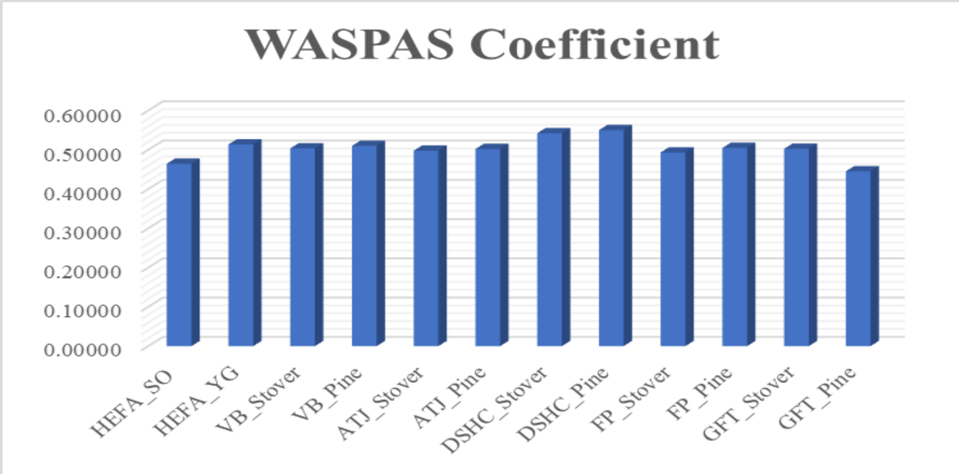

FIGURE 3. WASPAS Coefficient

Table 7 shows the WASPAS Coefficient value lambda 0.5. The WASPAS coefficient value DSHC_Pine = 0.55016, the highest value and GFT_Pine = 0.44532 is lowest value.

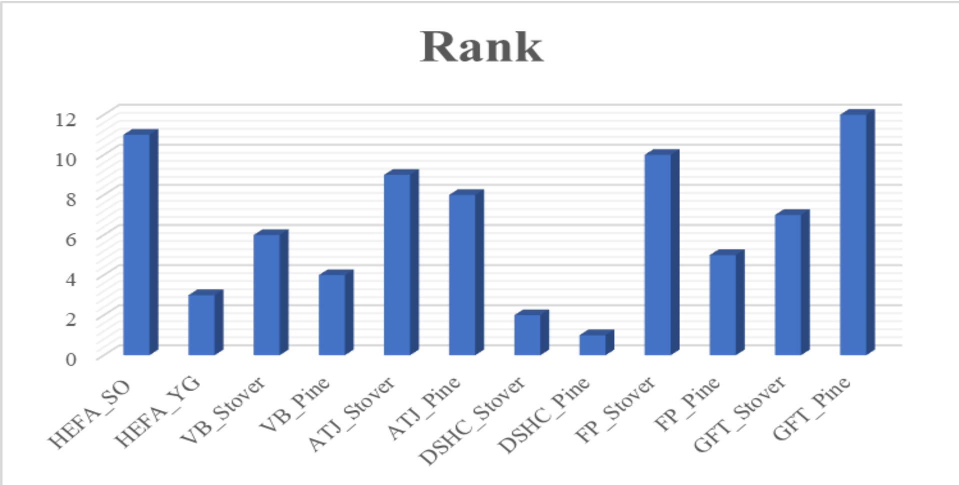

FIGURE 4. Sustainable aviation rank

Shows the figure 4 based on the findings obtained using the WASPAS method, the alternatives would be arranged in descending order from the top (first rank) to the bottom (lowest rank) on the chart. DSHC_Pine would be at the top with the first rank, and GFT_Pine would be at the bottom with the lowest rank.

5. CONCLUSION

This article discusses a number of intricate conclusions that came from a discourse of sustainable aviation policymaking. The procurement technology and managerial solutions, which carry far more weight than geographical factors, dominate ecological modernization in the hotly contentious sustainable aviation policy, which is a tumultuous mashup of competing discourses. the social facets of sustainability, for instance. While the focus of this essay, with some minor differences, is on sustainable alternative architecture in India, ecological modernization seems to be the major theme in other nations and locations. The methodology developed in this study integrates two main approaches, namely the WASPAS (Weighted Aggregating Sum Product Assessment) and rough AHP (Analytical Hierarchy Process) methods. The rough AHP is employed to rank and evaluate vendors, while the WASPAS method is utilized to determine the weight values of the evaluation criteria. To validate the model, vendors were selected from the business specializing in PVC furnishings based on nine different criteria. The results obtained using the approximate WASPAS methodology indicated that the fifth alternative emerged as the best choice. This conclusion was verified through sensitivity analysis, where the impact of modifying coefficient values and employing ensemble methods developed recently was assessed. The combination of the two methodologies provided a robust and reliable approach for selecting the most suitable vendors, ensuring effective decision-making in the context of PVC furnishing production. The approximate WASPAS technique has a perfect connection with the ratings of the other approaches, according to analysis of the data from the determination of Spearman's correlation coefficient. Sustainable aviation rank using WASPAS method, DSHC_Pine is got first rank and GFT_ Pine is got lowest rank

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