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A Fuzzy ANP-based Multi-Criteria Assessment of Barriers for Transformation to Sustainable Aviation: A Case Study in Vietnam

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Abstract—**The aviation industry is one of the most important sectors and a major driving force in the global economy. Over the past decades, the aviation industry has grown steadily to meet the increasing demand for transporting people and goods around the world. However, Vietnam's aviation sector faces a complex set of barriers in adopting sustainable aviation practices, which are critical for meeting long-term environmental and energy goals. Lack of Regulatory Frameworks (LRF), Investment and Financing Gaps (IFG), Infrastructure Incompatibility (II), Limited Technological Maturity (LTM), High Production Costs (HPC), Limited Feedstock Availability (LFA), Uncertain Environmental Benefits (UEB), and Airline Industry Resistance (AIR) are eight significant barriers evaluated and ranked in this work using a hybrid Fuzzy-Analytic Network Process (FANP). The analysis produced normalized priority weights indicating LRF (0.2125) and IFG (0.1986) based on expert input; next were II (0.1638) and LTM (0.1429). The lowest weights went to barriers, including AIR (0.0348) and UEB (0.0523). With LRF scoring (L=6.625, M=7.625, U=8.500) and IFG (L=6.125, M=7.625, U=8.125), fuzzy ratings support these results even more and indicate strong expert consensus on their relevance. Fuzzy logic enables one to capture ambiguity and different opinions among interested parties. The findings provide an organized, quantitative foundation for determining which policy and investment interventions should take center stage. This study offers Vietnamese decision-makers a more precise roadmap to overcome key obstacles to sustainable aviation adoption and accelerate the aviation industry's transition toward a low-carbon future.**

Keywords— **Sustainable aviation; barriers; multi-criteria decision-making; fuzzy algorithm; analytic network process.**

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I. INTRODUCTION

Transportation, particularly air freight, has long been regarded as one of the most efficient and time-sensitive methods for moving goods globally. It plays a pivotal role in high-value, perishable, or time-critical cargo movement [1]. Air transport has experienced rapid expansion globally in recent years, driven primarily by developing nations. Benefiting from its geographical location and integration into world supply chains, Vietnam has become a major competitor in this field. Growing foreign direct investment has led to the creation of manufacturing hubs, which are primarily dependent on-air cargo services to connect with worldwide customer markets. Vietnam is thus on a fast path of aviation expansion in both the passenger and goods sectors [2], [3].

Concurrently with the development of low-cost carriers, the aviation industry has undergone significant changes. By offering more reasonably priced travel options to the public and expanding accessibility and market reach, these carriers have enhanced their competitiveness. Driven by trade, tourism, and consumer demand, Vietnam's aviation industry has become progressively controlled by low-cost carriers [4], [5]. Although it boosts the economy, this increase in air traffic has led to significant environmental issues. The rising share of aviation greenhouse gas (GHG) emissions presents one of the most urgent issues. Without deliberate interventions, the worldwide aviation sector accounts for 2–3% of world CO_2 emissions, a percentage expected to increase [6]. Under rapid industrialization and urbanization, Vietnam's aviation-related carbon footprint is rising in line.

The industry is now under scrutiny to adopt sustainable aviation practices, aiming to meet these environmental demands, particularly in fuel selection and propulsion technologies. Policy and operational debate now revolve mainly around the investigation of alternative propulsion systems and sustainable aviation [7]. Regarding carbon emissions reduction, technical feasibility, infrastructure needs, economic viability, and operational safety, every alternative presents special benefits and trade-offs [8], [9].

The transition to sustainable aviation represents a critical step in decarbonizing the global aviation sector [10]. However, identifying the barriers that hinder the adoption of sustainable aviation is a complex task, especially in emerging markets such as Vietnam. Sustainable aviation deployment addresses overlapping technical, financial, regulatory, and infrastructure challenges, unlike those faced in conventional fuel transitions. These complexities are not only theoretical; they also reflect real-world situations in which airlines have to balance national policy priorities with international environmental commitments, infrastructure constraints with operational dependability, and cost efficiencies with carbon reduction [9], [11], [12]. Given such multidimensional terrain, meaningful strategic planning depends on accurate identification and prioritizing of obstacles.

The aviation sector in Vietnam is currently at a turning point. Driven by expanding middle-class travel demand, regional economic integration, and globalized trade, it is, on the one hand, fast-growing. Conversely, the industry is under increasing pressure to match global sustainability targets, most notably those set forth by the International Civil Aviation Organization and other climate agreements. Although sustainable fuels, including biodiesel, ammonia, methanol, hydrogen, other alternative fuels, and electric propulsion systems, are under increasing discussion as workable low-carbon substitutes to fossil fuels being used for transportation means, many questions surround their application [13]–[22]. These comprise low technical maturity, high upfront costs, regulatory fragmentation, and infrastructure incompatibility with current systems. Operational restrictions particular to Vietnam, including limited domestic R&D capacity, underdeveloped airport infrastructure, and a policy environment still adjusting to the demands of the green transition, compound these problems [23], [24].

Adoption of sustainable aviation faces natural interdependence and cannot be satisfactorily addressed alone. For example, limited feedstock availability, which is itself impacted by land-use restrictions and food-energy competition, is closely related to high production costs. Similarly, regulatory uncertainty can exacerbate financial risks, thereby hindering investment flows. Thus, a thorough strategy is needed that not only identifies these difficulties but also assesses their relative significance within a linked framework. This calls for the application of decision-support instruments that can manage the subjective nature of expert opinions as well as the complex interactions among multiple criteria.

The existing literature on sustainable aviation primarily focuses on technological development, lifecycle emissions, and global policy frameworks, with limited emphasis on prioritizing localized barriers in developing countries such as Vietnam. Most studies do not adequately address expert uncertainty in evaluating implementation challenges and lack a systematic multi-criteria analysis. Moreover, in the Vietnamese environment, a few studies combine quantitative modelling with qualitative expert judgment. This work closes that gap by methodically identifying, quantifying, and ranking the main obstacles preventing sustainable aviation acceptance in Vietnam using a Fuzzy Analytic Network Process (FANP). The novelty lies in offering a transparent and robust prioritization framework that combines expert-based fuzzy logic with network-based interdependence modelling. By highlighting the most significant obstacles, particularly those related to regulations, finance, and infrastructure, the authors aim to inform legislators and stakeholders, enabling them to develop focused plans. This study helps create localized decision-making tools that support Vietnam's shift toward a low-carbon aviation industry.

II. Materials and Method

A. Analytic Network Process

The ANP is based on the idea of a network model instead of a strict hierarchical tree. This lets it handle complex relationships between criteria, sub-criteria, and alternatives. The first step in ANP is to find decision clusters. These can be things like benefits, opportunities, costs, and risks, or in specific sectors like choosing SAF, they can be things like environmental performance, economic viability, infrastructure needs, and technological maturity. The things that affect each other directly or indirectly are found within and between these clusters. Once the network is set up, the next step is to compare the elements in pairs to find out how important or influential they are compared to each other. This is done by asking experts to rate them on a scale from 1 (equal importance) to 9 (extreme importance). These comparisons fill out a super matrix, which is a structured matrix that brings together all the relationships and dependencies. First, the super matrix doesn't have any weight. It just has the local priority vectors that come from comparisons. Then, it is weighed with the cluster weights and raised to powers (limit super matrix) to show how priorities change over time and how they come together. The final output gives global priority weights that show not only how important each criterion or alternative is on its own, but also how it affects the network. ANP can handle feedback loops and mutual influence because it is mathematically sound. This makes it a realistic model of complex decision-making situations, which is very important for fields like civil aviation where technology, cost, and sustainability all change at the same time [25], [26]. Within the framework of this research, several interrelated criteria, including environmental impact, technological readiness, cost, and infrastructure compatibility, influence the development of sustainable aviation fuel and propulsion. Using network clusters and pairwise comparisons, ANP helps to model these dependencies, so guaranteeing a more realistic assessment framework [27].

For example, cost efficiency could influence environmental preference; conversely, a strictly hierarchical model would be overlooked. Moreover, by capturing these internal influences among clusters, ANP's super matrix formulation helps one to compute global priorities [28], [29].

In this work, ANP provides a methodical approach to derive a comprehensive ranking of alternatives based on expert knowledge and context-specific priorities, enabling Vietnam's stakeholders and legislators to select the most balanced and future-ready aviation energy path.

B. Fuzzy Logic

Fuzzy logic is an essential tool for handling vagueness, ambiguity, and uncertainty inherent in human judgment, especially in decision-making processes that involve qualitative and subjective assessments [30], [31]. Unlike classical logic, where variables must be either 0 or 1, fuzzy logic variables can have a value anywhere between 0 and 1, representing partial truth. This makes it especially useful in situations where information is uncertain, imprecise, or vague, such as in natural language processing, control systems, and decision-making processes. Fuzzy logic enables machines to make more human-like decisions by evaluating a range of possibilities, making it widely applied in fields like robotics, automotive systems, and smart home technologies. In this paper, the assessment of sustainable aviation energy solutions mostly depends on expert opinions to evaluate non-quantifiable elements, including policy favorability, technological development, and safety perception [32]–[35]. The fuzzy approach avoids the rigidity of explicit numerical judgments by preserving the uncertainty of human logic [36], [37]. When researchers from diverse fields—aviation engineering, environmental science, policy, and economics—offer their pairwise comparisons among decision criteria or alternatives, fuzzy logic provides a common ground for aggregation and interpretation. In the Vietnamese setting, where empirical data on developing aviation technologies could be limited or changing, this is especially important. Fuzzy logic thus ensures that the resulting prioritization of aviation fuel options reflects both technical expertise and subjective experience under uncertainty, thereby increasing the dependability of expert-based evaluations [38], [39].

C. Hybrid ANP-Fuzzy Approach

The hybrid ANP-Fuzzy method offers a robust framework that synergistically combines the strengths of the Analytic Network Process and fuzzy logic to address complex, uncertain decision environments, making it highly relevant for evaluating sustainable aviation energy alternatives in Vietnam. Whereas fuzzy logic addresses the uncertainty and subjectivity in expert judgments, ANP catches the interdependencies and feedback among decision elements [40]. In this work, several criteria, including lifecycle emissions, energy density, infrastructure readiness, regulatory alignment, and economic cost, are used to choose between biodiesel blends, hydrogen, ATFs, and battery-based electric propulsion. Often linked and requiring subjective assessment from domain experts are these criteria.

The hybrid model enables the conversion of qualitative expert assessments into fuzzy numerical values by incorporating fuzzy logic into the ANP's pairwise comparison process, which subsequently facilitates the construction of a fuzzy super matrix. This ensures sufficient modelling of both the intricate network structure of the problem and the imprecision inherent in human thought. The final prioritization demonstrates a sophisticated understanding of sustainable aviation energy solutions in line with Vietnam's operational, developmental, and environmental goals. Therefore, the hybrid ANP-Fuzzy method provides a stronger and more context-sensitive decision-making tool for guiding aviation sustainability policies. A flowchart for hybrid ANP-Fuzzy is depicted in Figure 1.

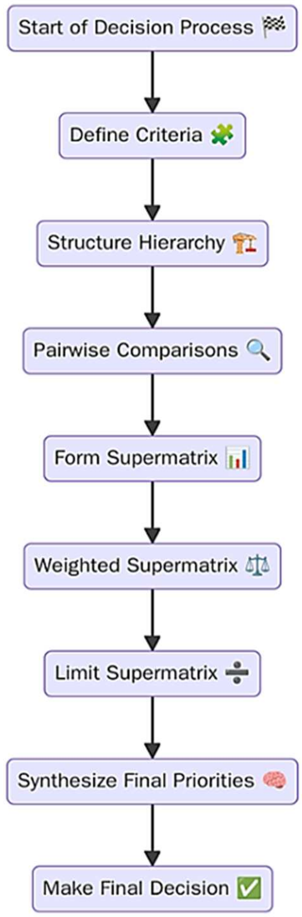

Fig. 1 Hybrid ANP-Fuzzy approach in MCDM

D. Barriers to Successful Adoption of Sustainable Fuels

1) High Production Costs (HPC): Sustainable aviation fuels (SAFs), including biodiesel, hydrogen, and synthetic alternatives, often involve higher production costs compared to conventional jet fuel. The higher costs are attributed to the adoption of newer technologies, research efforts, feedstock limitations, complex processing technologies, and scale inefficiencies. Experts observe that low-cost carriers find the price gap discouraging without significant investment or subsidies [41], [42]. This barrier is also faced by well-established airlines owing to stiff competition from LCC. Literature consistently emphasizes that economic unfeasibility remains the primary deterrent, particularly in developing countries like Vietnam, where airline margins are already constrained.

2) Limited Feedstock Availability (LFA): A consistent supply of sustainable and scalable feedstocks is a foundational requirement for bio-based SAFs. Experts contend that seasonal availability, land use restrictions, and competition with food production all impede consistent supply chains [43], [44]. Among the mentioned barriers, the impact of human food chain caused by the production of the first generation of biodiesel like mustard oil, sunflower oil, palm oil is the most prominent and well reported in literature. With a growing population and increasing agricultural reliance, Vietnam must strike a balance in land use. The literature also emphasizes that, although underdeveloped and necessary, feedstock variety presents a significant challenge for the long-term deployment of SAF in developing aviation markets.

3) Infrastructure Incompatibility (II): SAFs, such as those based on hydrogen or electricity, require significant modifications to current airport fueling systems, storage, and aircraft designs. Experts note that moving infrastructure across hundreds of flights every day calls for a large capital outlay, technical retrofitting, and regulatory changes [45], [46]. Even in the case of newer fuels being tested like hydrogen a complete infrastructure change or modification is needed. Studies indicate that infrastructure issues are particularly severe in Southeast Asia, where airport growth trails Western norms. This misalignment seriously reduces the operational readiness of green fuel substitutes.

4) Lack of Regulatory Frameworks (LRF): A unified regulatory roadmap guiding SAF certification, distribution, and use remains absent or poorly enforced in many countries, including Vietnam. Experts underline that inconsistency or changing national and international standards cause uncertainty for fuel companies and investors. While strong regulations—seen in the EU and the United States—are often cited as necessary drivers of SAF implementation, literature shows that policy fragmentation discourages innovation and slows supply chain development. This lack of regulations often causes project approvals to take longer and makes investors less confident in long-term SAF projects. Airlines that operate in more than one jurisdiction also have trouble following the rules because the rules for certification and blending are different in each place. To get past these problems, it's imperative to work together internationally and make sure that policies are consistent across countries. This will help the SAF market grow faster and build more infrastructure [47], [48].

5) Limited Technological Maturity (LTM): Many sustainable fuel technologies, particularly hydrogen and battery-electric systems, are still in developmental or demonstration phases. Experts contend that levels of technological readiness (TRLs) today are inadequate for commercial-scale acceptance. Local R&D capability for such technologies is still low in Vietnam, which drives more dependence on outside knowledge. The literature emphasizes that technology immaturity remains a basic obstacle for SAF integration in civil aviation without proven large-scale demonstrations and cost-reducing innovations. This gap in technological maturity makes stakeholders unsure about long-term performance, safety, and scalability. Vietnam is also cut off from leading innovation cycles because it doesn't have the infrastructure for testing at home and doesn't take part in many global pilot programs. These problems not only slow down deployment, but they also make the country more reliant on imported technologies, which makes it harder for local businesses to adapt and compete [42], [49].

6) Airline Industry Resistance (AIR): Due to cost pressures and risk aversion, airline operators—especially low-cost carriers—often resist adopting new fuels that may compromise profit margins or operational reliability. Experts point out that further aggravating this resistance are legacy fuel contracts, safety certification challenges, and performance metric uncertainty. According to the literature, airline commitment to SAF transition is still weak unless mandated or incentivized, especially in markets sensitive to prices like Southeast. The lack of proven economic benefits from early SAF adoption makes people more reluctant to participate. Airline management's operational conservatism puts established logistics first and limits exposure to untested fuel supply chains. Also, low consumer demand for green aviation options means that market forces don't have as much of an effect, which means that cost-saving strategies can take precedence over environmental concerns [50], [51].

7) Uncertain Environmental Benefits (UEB): While SAFs promise reduced greenhouse gas emissions, their full lifecycle impact varies widely depending on the feedstock, production method, and supply chain logistics. Experts emphasize the risk of greenwashing or marginal gains in the absence of adequate verification. Particularly when long distances of travel or land-use changes were taken into account, the literature records situations whereby the net emissions savings were either negligible or even negative. This uncertainty erodes investor and public trust in SAF assertions. Adding to the problem is the fact that there are no universally accepted methods for measuring lifecycle emissions, which makes reporting inconsistent across regions and projects. Differences in carbon accounting make it hard for stakeholders to agree and make it hard to compare SAF pathways fairly. Some producers also make it harder to evaluate SAFs fairly by not being clear about what they do. This makes people even more doubtful about the true environmental value of SAFs [41], [52].

8) Investment and Financing Gaps (IFG): Large-scale SAF deployment requires substantial upfront investments in R&D, infrastructure, and production capacity. Experts say that perceived risk, long payback times, and restricted access to green financing tools deter both public and private investment. Compounding this in Vietnam are conflicting national priorities and shallow capital markets. The literature emphasizes that the investment barrier will remain a fundamental difficulty absent mixed finance models, public-private partnerships, or carbon pricing systems. Moreover, investors often face difficulty in securing reliable data to assess long-term returns from SAF projects, which adds to risk aversion. The lack of specific financial tools for low-carbon aviation technologies makes it even harder for money to flow. In Vietnam, limited fiscal space and competing infrastructure needs often push SAF-related funding down the list of priorities. This reinforces the idea that these kinds of investments are risky and don't pay off [53]–[55].

These eight barriers form a comprehensive framework for evaluating the challenges Vietnam may face in decarbonizing its aviation sector, particularly when assessed using expert-driven MCDM techniques such as fuzzy ANP. This interconnectedness complicates policy design and strategic planning, making it harder to isolate and resolve individual issues effectively.

III. Results and discussion

A. ANP-based Ranking of Barriers

1) Step 1: Problem Definition and Criteria: Goal: Rank barriers to sustainable fuel implementation in Vietnam's aviation sector. Criteria (Barriers): Lack of Regulatory Frameworks (LRF), Investment and Financing Gaps (IFG), Infrastructure Incompatibility (II), Limited Technological Maturity (LTM), High Production Costs (HPC), Limited Feedstock Availability (LFA), Uncertain Environmental Benefits (UEB), Airline Industry Resistance (AIR). To collect the opinions of experts in this field a questionnaire was sent to experts in this field. Eight experts responded and gave their opinions on these barriers. The data was used for this MCDM analysis.

2) Step 2: Initial Decision Matrix: The aggregated expert decision matrix is calculated as the average scores from 8 experts, as given in Table 1.

3) Step 3: Normalize the Decision Matrix: Normalization is performed by dividing each average score by the total sum of scores (35.875), as shown in Table 2.

TABLE I
EXPERT DECISION MATRIX

Barrier	Abbreviation	Average Score
Lack of Regulatory Frameworks	LRF	7.625
Investment and Financing Gaps	IFG	7.125
Infrastructure Incompatibility	II	5.875
Limited Technological Maturity	LTM	5.125
High Production Costs	HPC	3.875
Limited Feedstock Availability	LFA	3.125
Uncertain Environmental Benefits	WEB	1.875
Airline Industry Resistance	AIR	1.25

TABLE II
NORMALIZED DECISION MATRIX

Barrier	Normalized Score
LRF	0.213
IFG	0.199
II	0.164
LTM	0.143
HPC	0.108
LFA	0.087
UEB	0.052
AIR	0.035

4) Step 4: Pairwise Comparison Matrix: The pairwise comparison matrix was constructed using the normalized scores such that: $a_{ij} = w_i/w_j$ where w_i and w_j The normalized weights of barriers i and j, respectively. The pairwise comparison matrix reflects how each barrier is perceived concerning the others, based on their normalized weights. In this regard, LRF seems to be the most critical barrier since it shows better values than the others and indicates that professionals give it top importance. IFG also ranks highly; comparison values suggest it is somewhat less important than LRF, but still significant in the decision-making process. II regularly ranks above many of the other remaining obstacles, having a strong middle position. With lower comparison values throughout the matrix, LFA, UEB, and AIR are seen as less critical; LTM and HPC show modest influence. These findings enable decision-makers to concentrate better on resources and attention by highlighting the most urgent problems noted by professionals.

Apart from supporting consistency in opinions, the matrix provides a basis for additional study inside the ANP framework. It improves openness and structure in prioritizing obstacles by turning professional opinions into unambiguous analogs. In complex situations, this approach helps to make more wise and balanced decisions. The Pairwise Comparison Matrix is shown in Table 3.

TABLE III
PAIRWISE COMPARISON MATRIX

	LRF	IFG	II	LTM	HPC	LFA	UEB	AIR
LRF	1	1.07	1.298	1.488	1.968	2.44	4.067	6.1
IFG	0.934	1	1.213	1.39	1.839	2.28	3.8	5.7
II	0.77	0.825	1	1.146	1.516	1.88	3.133	4.7
LTM	0.672	0.719	0.872	1	1.323	1.64	2.733	4.1
HPC	0.508	0.544	0.66	0.756	1	1.24	2.067	3.1
LFA	0.41	0.439	0.532	0.61	0.806	1	1.667	2.5
UEB	0.246	0.263	0.319	0.366	0.484	0.6	1	1.5
AIR	0.164	0.175	0.213	0.244	0.323	0.4	0.667	1

5) Step 5: Calculate Priority Vector: The priority vector is calculated by taking the geometric mean of each row and normalizing the resulting vector. Table 4 and Figure 2 depict the priority weights assigned to various barriers affecting decision-making in the context of sustainable aviation fuel implementation using the ANP approach. LRF has the most weight among the found obstacles, 0.2125, indicating it is the most important problem to solve. Emphasizing the need for great financial support and infrastructure readiness, it is closely followed by IFG with a weight of 0.1986 and II at 0.1638. With a value of 0.1429, LTM also has a significant influence, implying that constant innovation is vital. HPC at 0.108, LFA at 0.081, UEB at 0.0523, and AIR at just 0.0348 have lower priorities. This distribution highlights the strategic areas that require prompt policy and investment attention for effective sector transformation.

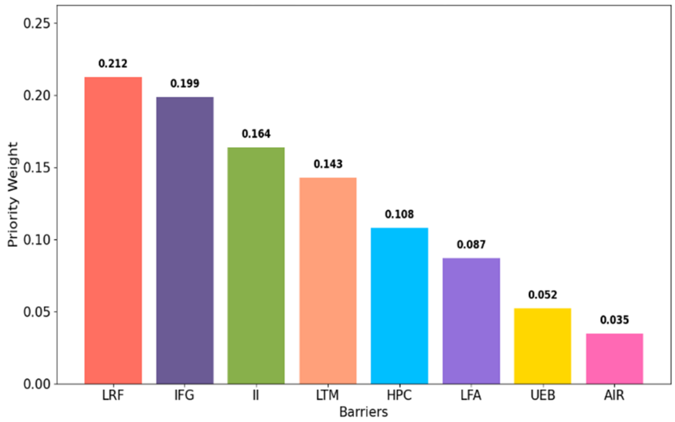

Fig. 2 Priority weights of each barrier

TABLE IV
PRIORITY WEIGHTS OF EACH BARRIER

Barrier	Priority Weight
LRF	0.2125
IFG	0.1986
II	0.1638
LTM	0.1429
HPC	0.108
LFA	0.0871
UEB	0.0523
AIR	0.0348

6) Step 6: Consistency Check: Calculate Consistency Index (CI) and Consistency Ratio (CR) to ensure reliability of the pairwise comparison matrix. CR < 0.1 indicates acceptable consistency.

λ_max = 8.0000
Consistency Index (CI) = 0.0000
Random Index (RI for n = 8) = 1.41
Consistency Ratio (CR) = 0.0000
The matrix is consistent (CR < 0.1).

B. Fuzzy MCDM Analysis

1) Fuzzification of each Ratings: Each expert rating (scale of 1 to 9) is transformed into a triangular fuzzy number (TFN).

The following TFNs are used:
1: (1, 1, 3)
2: (1, 2, 3)
3: (2, 3, 4)
4: (3, 4, 5)
5: (4, 5, 6)
6: (5, 6, 7)
7: (6, 7, 8)
8: (7, 8, 9)
9: (8, 9, 9)

2) Aggregated Fuzzy Decision Matrix: The aggregated fuzzy ratings for each barrier (L, M, U) are listed in Table 5, and the fuzzy score trends are shown in Figure 3. The mean fuzzy score bar chart to show the comparison is depicted in Figure 4.

TABLE V
AGGREGATED FUZZY RATINGS FOR EACH BARRIER

Barrier	L	M	U
LRF	6.625	7.625	8.500
IFG	6.125	7.125	8.125
II	4.875	5.875	6.875
LTM	4.125	5.125	6.125
HPC	2.875	3.875	4.875
LFA	2.125	3.125	4.125
UEB	1.125	1.875	3.125
AIR	1.000	1.250	3.000

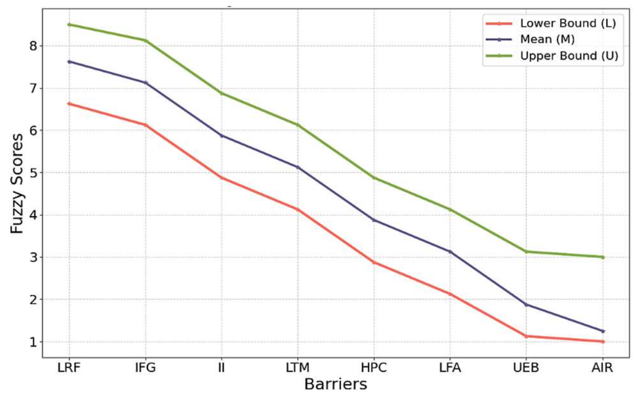

Fig. 3 Fuzzy score trends for each barrier

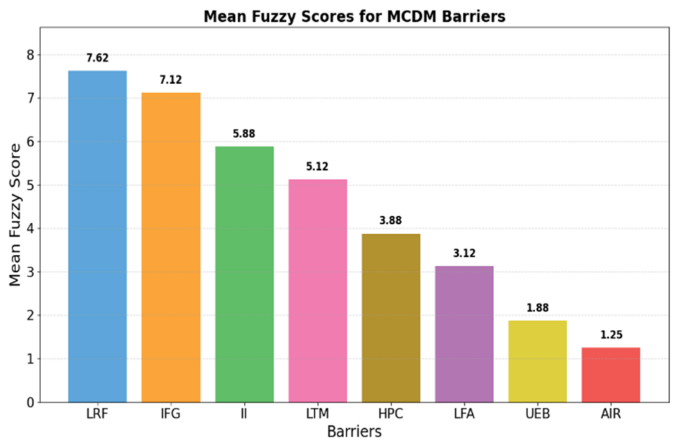

Fig. 4 Mean fuzzy score for each barrier

The combined fuzzy ratings for every barrier draw attention to the perceived relevance and intensity of different difficulties in the decision-making process. With L=6.625, M=7.625, and U=8.500, LRF exhibits the highest fuzzy values and is thus regularly regarded as the most important barrier. IFG (6.125, 7.125, 8.125) follows closely and likewise ranks highly across all limits. With II scoring somewhat higher than LTM, which falls in a moderate importance range, structural issues remain a clear top priority. Though they reflect less concern, barriers like HPC and LFA are still important. While UEB and AIR show the lowest scores, these are seen as minor problems in relation. The fuzzy bounds (L, M, U) offer information on expert consensus and uncertainty; narrower gaps indicate agreement while wider gaps imply different expert opinions. The results generally support giving LRF, IFG, and II top priority in strategic planning and policy development. The overall distribution of fuzzy scores illustrates the hierarchy of perceived challenges, highlighting how certain barriers prevail in expert concerns throughout strategic levels. The persistently elevated levels of LRF and IFG highlight the ingrained regulatory fragmentation and governance inefficiencies, which experts consider fundamental obstacles. In contrast, the diminished ratings for UEB and AIR do not signify irrelevance but rather suggest that these concerns are now less urgent within the overarching problem framework. The fluctuating breadth of fuzzy intervals underscores differences in expert confidence, illustrating the complexity and ambiguity involved in evaluating obstacles in the constantly advancing field of sustainable aviation fuel.

IV. CONCLUSION

This research provides a data-driven prioritization of the major barriers impeding sustainable aviation adoption in Vietnam, using a Fuzzy-Analytic Network Process framework grounded in expert judgment. With a normalized weight of 0.2125, Lack of Regulatory Frameworks (LRF) ranks highest among all the barriers, underscoring the immediate need for consistent SAF rules in Vietnam. With a weight of 0.1986, Investment and Financing Gaps (IFG) closely follow and underline the need for financial systems including public-private collaborations and green investment incentives. Third at 0.1638 is Infrastructure Incompatibility (II), which emphasizes the need for capital-intensive improvements to fueling, storage, and aircraft systems. Analysis of fuzzy logic supports these priorities. With L=6.625, M=7.625, U=8.500, LRF got the highest fuzzy rating; followed by IFG (L=6.125, M=7.625, U=8.125), so indicating strong agreement on their criticality. By contrast, Airline Industry Resistance (AIR) and Uncertain Environmental Benefits (UEB) were assigned lower weights (0.0348 and 0.0523, respectively), implying they are rather less obstructive but still rather important. Particularly given Vietnam's reliance on imported technology and limited airline profit margins, barriers like Limited Technological Maturity (0.1429) and High Production Costs (0.108) also merit consideration. This multi-criteria analysis helps to pinpoint areas with high impact where focused intervention will have the best results. SAF scalability will depend on addressing top-ranked challenges including infrastructure readiness, financing availability, and regulatory clarity. These results provide strategic information for Vietnamese officials and investors to negotiate a sustainable road for aviation decarbonization.

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