Strategic Decision-Making in the Offshore Fleet: The MADRID Method for eVTOL Selection for Operational Optimization and Sustainability

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Abstract

The integration of electric vertical take-off and landing vehicles (eVTOLs) into offshore operations is a complex strategic challenge involving technical, operational, environmental, and regulatory factors. This study presents the MADRID Method, a structured decision-support framework developed for the strategic selection of eVTOL platforms in offshore fleets. The method addresses decision contexts marked by uncertainty, interdependent criteria, and severe operational constraints typical of offshore environments. The MADRID Method organizes the decision process into systematic stages, including the hierarchical definition of criteria, the objective assessment of alternatives, and the consolidation of results into a strategic ranking. It emphasises transparency, traceability, and reproducibility, supporting its use by operators, policymakers, and advanced air mobility planners. Its applicability is demonstrated through a case study comparing different eVTOL models according to operational efficiency, environmental sustainability, safety, and regulatory compliance in the offshore context. The results show that the method captures key trade-offs among critical criteria and provides consistent support for decision-making. By offering a framework tailored to offshore realities, this study contributes to the assessment of emerging air mobility technologies and supports the sector's transition toward safer, more efficient, and more sustainable solutions.

Keywords: *MADRID Method, MCDA, Advanced Air Mobility, Offshore, Operations Sustainability.*

1. Introduction

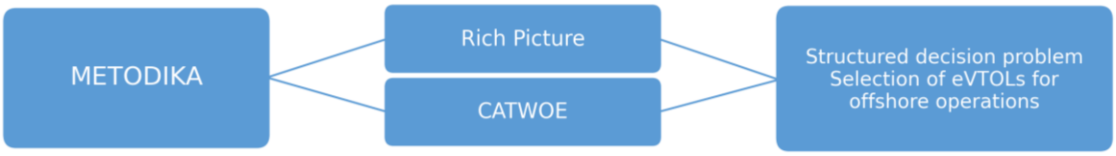
Advanced Air Mobility (AAM) has been consolidating itself as one of the main drivers of transformation in contemporary transport systems, driven by the development of electric vertical take-off and landing aircraft (eVTOLs), regulatory advances, and the growing demand for more efficient and sustainable solutions. Much of the early application of AAM has been concentrated in urban environments, but there is growing interest in adapting these technologies to offshore operations in the energy, oil and gas, and maritime logistics sectors, where dependence on air transport is high. Offshore operations present a specific set of operational, environmental, and regulatory challenges, including adverse weather conditions, physical space limitations, demanding safety requirements, and high operating costs associated with the use of conventional helicopters.

With the arrival of these aircraft, eVTOLs emerge as a potentially advantageous alternative, offering lower noise emissions, reduced operating costs, and greater alignment with decarbonization goals. However, acquiring these aircraft for critical maritime environments requires complex strategic decisions, since the available models differ in technical performance, regulatory maturity, system robustness, and suitability for the offshore context. Selecting eVTOL models for this type of operation is a multicriteria decision problem, with multiple alternatives that must be evaluated according to heterogeneous and conflicting criteria. The presence of uncertainties associated with emerging technologies reinforces the need for structured approaches capable of integrating quantitative data, qualitative criteria, and objective judgments in a transparent and traceable manner.

This study aims to apply the MADRID Method as a decision-support framework for the strategic selection of crewed eVTOL aircraft intended for offshore operations. The method combines problem-structuring techniques, objective weighting of criteria, clustering of alternatives, and multicriteria ranking, allowing the complexity of the decision space to be addressed without the premature exclusion of alternatives. The research is guided by the question of how to structure and support, in a robust and transparent way, the selection of crewed eVTOLs for offshore operations while considering multiple technical, operational, environmental, and regulatory criteria, thus contributing both to the methodological advancement of multicriteria tools applied to Advanced Air Mobility and to the debate on the feasibility and strategic requirements of adopting eVTOLs in offshore environments.

Contemporary decision-support approaches emphasise that the application of purely quantitative models or the adoption of intuitive decisions tends to generate inconsistent or biased results. Methodological platforms dedicated to structuring complex problems, such as METODIKA, emphasise that a systemic understanding of the problem must precede any attempt at formal evaluation or comparison of alternatives, since this is essential for making stakeholder perspectives explicit and aligned and for reducing cognitive bias. METODIKA acts as a guiding element in the problem-structuring phase, from which specific instruments are defined to support the systemic and conceptual understanding of the analysed context (Figure 1).

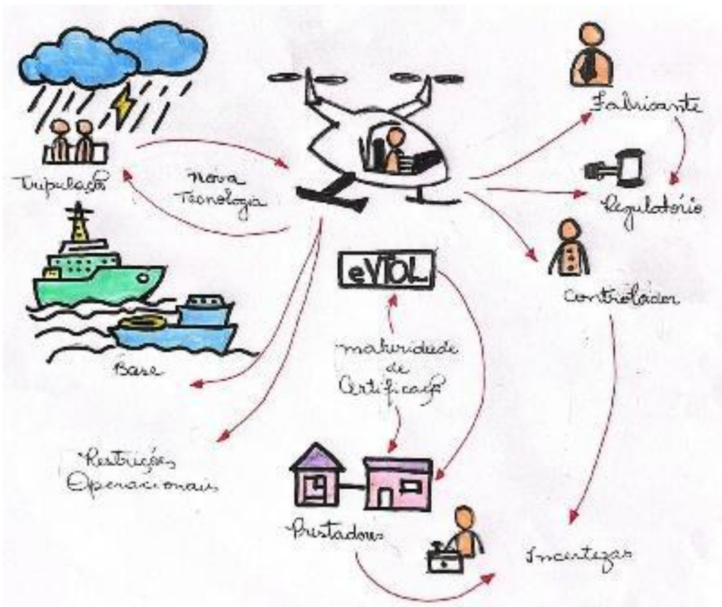
Figure 1 – METODIKA in structuring the decision problem for offshore eVTOLs



Source: Authors (2026)

In the problem-structuring process, the Rich Picture (Figure 2) is a visual resource that supports the identification and analysis of the interactions, conflicts, and flows present in the studied system.

Figure 2 – Description of the eVTOL selection problem using a Rich Picture



Source: Authors (2026)

At the problem-structuring stage, CATWOE (Table 1) was applied to synthesise the components of the system under analysis, identifying customers, actors, the transformation process, worldview, owners, and environmental constraints, since it promotes the alignment of stakeholders' understanding of the problem and helps define the criteria used in the multicriteria stage.

Table 1 – Structuring of the decision problem using CATWOE

Elements	C (customers)	A (actors)	T (transformation)	W (worldview)	O (owners)	E (environmental constraints)
Description	Offshore operators and workers, society benefited from safe and sustainable solutions.	Pilots; logistics operators; eVTOL manufacturers; maintenance teams; aeronautical regulatory authorities; offshore infrastructure managers	To transform the complex need for safe, efficient, and sustainable offshore air transport into a structured problem of strategic selection of eVTOL models	Offshore operations are high-risk environments in which safety and reliability must be treated as priorities, requiring a systematic and responsible technological approach.	Decision-makers, corporate managers, and regulatory authorities	Current aeronautical regulation; severe weather conditions; current technical limitations; existing offshore infrastructure (helidecks, coastal bases); safety requirements and tolerance to failure

Source: Authors (2026)

The research question underlying this study concerns how to support, in a structured and transparent way, the strategic selection of crewed eVTOL aircraft intended for offshore operations through multiple technical, economic, environmental, and regulatory criteria. Thus, the general objective of the article is to propose and apply the MADRID Method as a decision-support framework for selecting crewed eVTOLs for the offshore sector, integrating objective weighting techniques, clustering, and multicriteria ranking. In this context, the study seeks to answer the following research question: how can the strategic selection of crewed eVTOL aircraft intended for offshore operations be supported in a structured, transparent, and non-eliminatory way while considering multiple technical, operational, environmental, and regulatory criteria? To this end, the application of the MADRID Method is proposed as an integrated decision-support framework combining systemic problem structuring, objective weighting of criteria, clustering of alternatives, and multicriteria ranking.

The main contributions of the study lie in expanding the domain of application of the MADRID Method to the offshore context, in the formal integration between Soft Systems Methodology and MCDA in strategic aeronautical decisions, and in generating analytical support for operators and policymakers in the process of adopting eVTOLs in critical maritime environments.

2. Theoretical Framework

2.1. Advanced Air Mobility and eVTOLs

Advanced Air Mobility (AAM) refers to an emerging ecosystem of aeronautical solutions that incorporates new electric or hybrid propulsion technologies, advanced automation, and new operational models for passenger and cargo transport (Garrow; German; Leonard, 2021). At the centre of this ecosystem are electric vertical take-off and landing aircraft (eVTOLs), characterised by distributed propulsion architectures, high energy efficiency, and the potential to reduce emissions and noise compared with conventional aircraft (Brunelli; Ditta; Postorino, 2023).

Recent studies highlight the rapid technological advancement of these aircraft, driven by private investment, public decarbonization policies, and regulatory initiatives aimed at certifying next-generation aircraft (Di Mascio; Del Serrone; Moretti, 2025). It is observed that a large share of the literature is concentrated on urban applications, whereas applications in industrial and offshore environments remain less explored despite their high strategic potential (Wu; Zhang, 2021).

2.2. Offshore operations and aeronautical challenges

Offshore operations represent one of the most demanding models for civil aviation, involving long distances over water, adverse weather conditions, infrastructure constraints, and strict operational safety requirements (Du et al., 2024; Elizebeth et al., 2025). Conventional helicopters have been the main means of transporting personnel and cargo to maritime platforms, despite their high operating costs and significant environmental impact.

Crewed eVTOL aircraft emerge as promising alternatives for short- and medium-range missions, reduced-team transport, and logistical support operations. However, adopting these aircraft in the offshore environment imposes additional requirements, such as redundancy of critical systems, compatibility with existing helidecks, and adherence to rigorous regulatory standards (ANAC, 2021; Calogero, 2024). These factors reinforce the need for analytical approaches capable of systematically integrating multiple evaluation dimensions.

2.3. Structuring complex problems in sociotechnical systems

Contemporary methodological platforms aimed at decision support reinforce the importance of Problem Structuring Methods (PSMs) as an initial stage in complex decision-making processes. Pereira et al. (2025) emphasises that proper problem structuring should precede the application of quantitative methods, reducing the risk of decisions based on mathematically correct models that are nevertheless misaligned with the real system.

This perspective is relevant in offshore AAM because technical data may be incomplete or asymmetric across manufacturers. The use of PSMs helps align stakeholder expectations, delimit the scope of the problem, and ensure that the evaluation criteria reflect the strategic objectives of the system (Alinezhad; Khalili, 2019).

The strategic selection of crewed eVTOL aircraft for offshore operations is characterised as a complex sociotechnical problem involving multiple actors, potentially conflicting objectives, regulatory constraints, and high levels of technological uncertainty. To deal with this complexity at the introductory stage of the study, a systemic problem-structuring approach grounded in Soft Systems Methodology (SSM) was adopted.

The Rich Picture was used as a visual representation of the decision system, making it possible to holistically explain the main actors, information flows, operational constraints, conflicts, and objectives associated with the incorporation of eVTOLs into offshore operations. This type of representation favours systemic thinking and the construction of a shared understanding of the problem in contexts marked by high complexity and multiple interdependencies (Checkland; Scholes, 1999; Checkland, 1989; Armson, 2011).

The CATWOE technique was employed to structure the elements of the analysed system by identifying Customers, Actors, the Transformation Process, Worldview, Owners of the system, and Environmental Constraints. CATWOE makes it possible to translate the Rich Picture's visual representation into a coherent and logical formulation of the problem, reducing conceptual problems and aligning the different perspectives of the stakeholders involved (Checkland, Poulter, 2020). The CATWOE analysis contributed to delimiting the boundaries of the decision system and to defining the evaluation criteria used in the multicriteria stage.

2.4. Multicriteria Decision Analysis (MCDA) methods

Multicriteria Decision Analysis (MCDA) methods comprise a set of approaches used to evaluate alternatives under multiple criteria in contexts characterised by trade-offs and conflicting objectives (Sahoo; Goswami, 2023). These methods allow the integration of quantitative and qualitative criteria, providing a structured basis for comparing and ranking alternatives.

In the literature, different MCDA methods have been applied to transportation and infrastructure problems. The application of these methods to emerging technologies requires caution, since the availability of complete data or technological stability is not always present (Mukhametzyanov, 2021).

The MADRID Method (Multicriteria Analysis for Decision-support in Innovation and Development) was developed to deal with decision problems associated with innovation, emerging technologies, and complex systems (Pina Corriça et al., 2025). Unlike compensatory approaches, MADRID combines problem structuring, objective weighting based on the information contained in the data, and clustering techniques to reduce decision complexity.

This approach makes MADRID suitable for evaluating eVTOL models in the offshore environment, where multiple alternatives can be found at different stages of technological and regulatory maturity. In addition, the method makes it possible to deal with uncertainty and data heterogeneity while preserving analytical coherence and decision traceability (Stanujkić et al., 2021).

The MADRID Method emerges as a framework for supporting complex decisions and provides the conceptual basis for the methodology, showing that the strategic selection of eVTOLs for offshore operations requires an integrated approach capable of articulating AAM fundamentals, the specific challenges of the maritime environment, problem-structuring techniques, and advanced multicriteria methods.

3. Methodology

This study explores the MADRID Method (Multicriteria Analysis for Decision Through Ranking and Integrated Decomposition) as a decision-support framework for the strategic selection of crewed eVTOL models applicable to offshore operations. The method was proposed by Pina Corriça et al. (2025) to deal with problems characterised by a large number of alternatives, multiple criteria, and informational heterogeneity, making it appropriate for contexts of high technological uncertainty.

The MADRID Method avoids eliminating alternatives, internalising differences in technological maturity and regulatory status as evaluation criteria (Pina Corriça et al., 2025). This characteristic makes the method pertinent to the domain of Advanced Air Mobility, where solutions are found at different stages of development (Garrow; German; Leonard, 2021; Brunelli; Ditta, Postorino, 2023).

The method integrates Problem Structuring Methods (PSMs), normalisation and weighting techniques, unsupervised clustering, and multicriteria ranking, thereby ensuring logical coherence, analytical traceability, and decision transparency.

Unlike widely used multicriteria methods such as AHP, TOPSIS, or ELECTRE, which tend to assume compensatory structures or require the prior exclusion of alternatives, the MADRID Method was conceived for contexts of innovation and uncertainty in which solutions are found at different stages of technological and regulatory maturity. Its non-eliminatory, data-informed approach makes it possible to preserve emerging alternatives in the decision process, which is particularly relevant in domains such as offshore Advanced Air Mobility.

3.1. Alternatives and criteria of the decision matrix

The alternatives correspond to crewed eVTOL models with a formal certification process initiated with aeronautical authorities (FAA, EASA, ANAC) and potential application in offshore operations, considering requirements such as minimum range, payload capacity, safety, and operational feasibility over water.

The decision problem is defined by a set of alternatives: A = {a1, a2, a3, …, a10}. The final selection resulted in ten alternatives, a number considered adequate to ensure technological diversity without compromising the analytical robustness of the study, as recommended by the MADRID framework (Table 2).

Table 2 – Description of the alternatives

Alternative	Model	Manufacturer	Country of origin	Official link
A1	Archer Midnight	Archer Aviation	United States	https://www.archer.com/
A2	Joby S4	Joby Aviation	United States	https://www.jobyaviation.com/
A3	VX4 / Valo	Vertical Aerospace	United Kingdom	https://vertical-aerospace.com/
A4	ALIA-250	BETA Technologies	United States	https://www.beta.team/
A5	Lilium Jet	Lilium GmbH	Germany	https://lilium.com/
A6	Eve eVTOL	Eve Air Mobility (Embraer)	Brazil	https://eveairmobility.com/
A7	CityAirbus NextGen	Airbus	France	https://www.airbus.com/
A8	Jaunt Journey	Jaunt Air Mobility	United States	https://jauntairmobility.com/
A9	VoloCity	Volocopter GmbH	Germany	https://www.volocopter.com/
A10	VoloConnect	Volocopter GmbH	Germany	https://www.volocopter.com/

Source: Authors (2026)

The choice of crewed eVTOL aircraft is justified by current operational safety, certification, and critical personnel transport requirements in offshore operations, in which fully uncrewed solutions still present significant regulatory and operational limitations.

3.2. Criteria of the decision matrix

A set of criteria was defined: C = {c1, c2, c3, …, c10}, with 10 criteria organised into six dimensions: operational, technical, safety, regulatory, environmental, and strategic (Table 3). This definition meets the principle of complete multicriteria evaluation, as discussed in the decision-support literature (Alinezhad; Khalili, 2019).

Table 3 – Description of the criteria

Criterion	Description	Unit of measure	Monotonicity
C1 Cost	The estimated average cost of the eVTOL	US$	Minimization
C2 Operational range	Maximum operational distance with minimum reserve	km	Maximization
C3 Maximum speed	Maximum cruise speed	km/h	Maximization
C4 Payload	Maximum transportable payload capacity	kg	Maximization
C5 Passenger capacity	Maximum number of passengers (excluding pilot)	Passengers	Maximization
C6 Operational noise	Average noise level measured or declared in cruise	dB	Minimization
C7 Recharge time	Time required for full recharge or turnaround between flights	Minutes	Minimization
C8 Certification maturity	Stage of the regulatory process	Ordinal scale 1-5	Maximization
C9 Suitability for the offshore environment	Degree of compatibility with offshore operations	Ordinal scale 1-5	Maximization
C10 Redundancy and safety architecture	Level of redundancy of critical systems	Ordinal scale 1-5	Maximization

Source: Authors (2026)

The criteria were classified as benefit criteria (the higher, the better the performance) and cost criteria (the lower, the better the performance), in order to properly guide the normalisation process and avoid distortions in the comparison among alternatives.

3.3. Construction of the decision matrix

The initial decision matrix is defined as $X = [x_{ij}]$, where xij represents the performance of the alternative. The values in the matrix may be obtained from public technical data, regulatory documentation, or structured expert judgment accepted in MCDA (Checkland; Poulter, 2020). Table 4 presents the decision matrix.

Table 4 – Decision matrix

Alternatives	Cost US$ mi	Range km	Speed km/h	Payload kg	Passengers units	Noise dB	Recharge min	Certification scale 1-5	Offshore scale 1-5	Safety scale 1-5
Monotonicity	**min**	**max**	**max**	**max**	**max**	**min**	**min**	**max**	**max**	**max**
A1 Archer Midnight	5.0	161	241	453	4	45	10	4	3	5
A2 Joby S4	4.8	161	322	450	4	48	8	4	3	5
A3 VX4 / Valo	4.5	161	241	513	4	50	8	3	3	5
A4 ALIA-250	4.0	463	285	635	5	50	9	4	5	5
A5 Lilium Jet	6.0	300	300	500	6	48	10	3	4	5
A6 Eve eVTOL	3.5	100	237	480	4	48	8	3	3	4
A7 CityAirbus NextGen	5.5	210	280	320	4	50	8	3	4	5
A8 Jaunt Journey	4.2	80	120	500	4	50	10	3	2	4
A9 VoloCity	2.0	35	110	250	1	50	10	4	1	4
A10 VoloConnect	3.8	100	250	340	2	48	10	3	2	4

Source: Authors (2026)

3.4. Normalisation of the decision matrix

The matrix was obtained by linear min-max normalisation, ensuring comparability among criteria of different natures and units. Cost and benefit criteria were treated differently, as established by the MADRID Method. The procedure ensures that all normalized values belong to the interval [0,1], preserving the relative performance relationships among the alternatives (Table 5).

For maximization criteria: $rij = \frac{(xij - \min(xj))}{(\max(xj) - \min(xj))}$

For minimization criteria: $rij = \frac{(\max(xj) - xij)}{(\max(xj) - \min(xj))}$

resulting in the normalized matrix: $R = [rij]$.

Table 5 – Normalised matrix

Alternatives	Cost US$ mi	Range km	Speed km/h	Payload kg	Passengers units	Noise dB	Recharge min	Certification scale 1-5	Offshore scale 1-5	Safety scale 1-5
A1 Archer Midnight	0.30	0.31	0.54	0.00	0.60	1.00	0.00	1.00	0.50	1.00
A2 Joby S4	0.34	0.31	1.00	0.00	0.60	0.00	0.00	1.00	0.50	1.00
A3 VX4 / Valo	0.40	0.31	0.54	0.41	0.60	0.00	0.00	0.00	0.50	1.00
A4 ALIA-250	0.50	1.00	0.75	1.00	0.80	0.00	0.00	1.00	1.00	1.00
A5 Lilium Jet	0.00	0.63	0.81	0.41	1.00	0.00	0.00	0.00	0.75	1.00
A6 Eve eVTOL	0.63	0.15	0.43	0.41	0.60	0.00	0.00	0.00	0.50	0.00
A7 CityAirbus NextGen	0.13	0.44	0.72	0.41	0.60	0.00	0.00	0.00	0.75	1.00
A8 Jaunt Journey	0.45	0.10	0.04	0.41	0.60	0.00	0.00	0.00	0.25	0.00
A9 VoloCity	1.00	0.00	0.00	0.41	0.00	0.00	0.00	1.00	0.00	0.00
A10 VoloConnect	0.55	0.15	0.61	0.41	0.20	0.00	0.00	0.00	0.25	0.00

Source: Authors (2026)

3.5. Criteria weighting (DIBR)

The DIBR method was adopted because it makes it possible to obtain objective weights from the variability and information contained in the data, reducing dependence on subjective judgments and making it particularly suitable for contexts characterised by technological uncertainty and informational asymmetry, such as eVTOL selection.

Moreover, the choice of DIBR is consistent with the literature that highlights the importance of structured weighting in complex problems (Mukhametzyanov, 2021) (Figure 3).

Figure 3 – Description of DIBR

Source: Authors (2026)

The criterion weights were obtained by means of Decision Information Based Ranking (DIBR), which uses the statistical information contained in the normalised matrix. The procedure is described by the mean and standard deviation formulas and by the definition of the amount of information associated with each criterion.

The weights wj were calculated based on the formula $wj = Ij / \Sigma Ik$, where Ij is the amount of information associated with criterion Cj, calculated as $Ij = \sigma j \cdot \bar{r}j$. Table 6 presents the criterion weights obtained by the DIBR method.

Table 6 – Criteria weighting (DIBR)

Alternative	r̄j	σj	Ij	wj
A1 Archer Midnight	0.63	0.19	0.120	0.086
A2 Joby S4	0.55	0.16	0.088	0.071
A3 VX4 / Valo	0.61	0.28	0.171	0.150
A4 ALIA-250	0.58	0.14	0.081	0.068
A5 Lilium Jet	0.60	0.23	0.138	0.115
A6 Eve eVTOL	0.52	0.05	0.026	0.023
A7 CityAirbus NextGen	0.47	0.00	0.000	0.000
A8 Jaunt Journey	0.73	0.25	0.183	0.152
A9 VoloCity	0.69	0.18	0.124	0.106
A10 VoloConnect	0.78	0.33	0.257	0.228

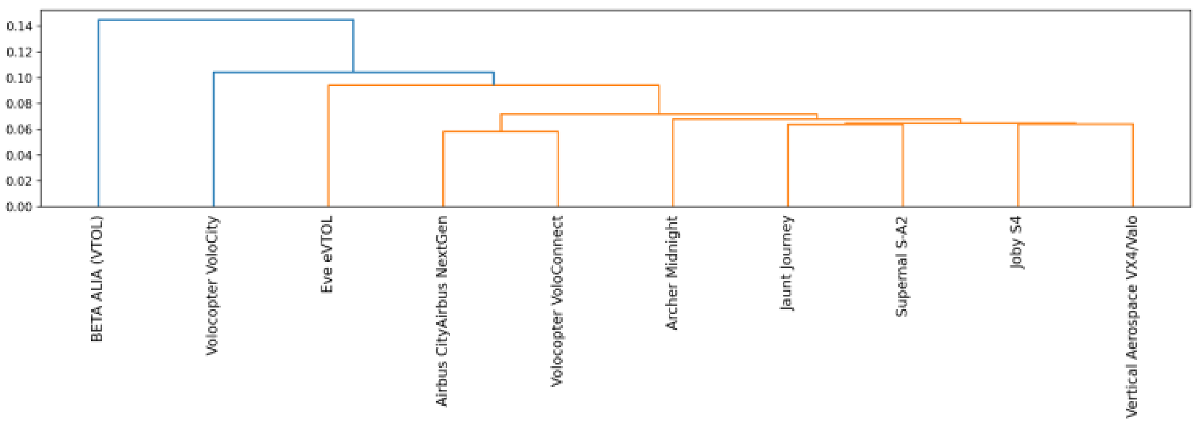
Source: Authors (2026)

3.6. Clustering of alternatives

To reduce the complexity of the decision space, agglomerative hierarchical clustering was applied using the single-linkage criterion and Euclidean distance. The dissimilarity between two alternatives ai and ak was calculated as $d(ai, ak) = \sqrt{\Sigma(vij - vkj)^2}$.

The optimal number of clusters was determined based on the silhouette index (Rousseeuw, 1987), as already described in the methodology. Figure 4 presents the hierarchical dendrogram resulting from clustering the alternatives (Pina Corriça et al., 2025).

Figure 4 – Description of DIBR



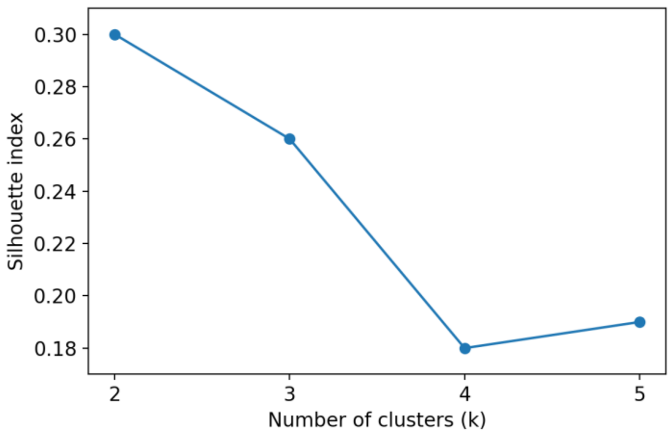
Source: Authors (2026)

3.7. Determination of the optimal number of clusters

The definition of the optimal number of clusters was carried out using the silhouette index proposed by Rousseeuw (1987) and Corriça et al. (2024, 2025). For each alternative ai, the silhouette coefficient $s(i)$ is calculated as $s(i) = [b(i) - a(i)] / max\{a(i), b(i)\}$, where $a(i)$ is the average distance from ai to the other alternatives belonging to the same cluster, and b(i) is the smallest average distance from ai to the alternatives of any other cluster. The value of $s(i)$ varies within the interval $[-1, 1]$, with values close to 1 indicating an adequate allocation of the alternative to its cluster. The adopted number of clusters is the one that maximises the mean silhouette value, ensuring the best trade-off between internal cohesion and separation between groups.

Figure 5 presents the average silhouette values for different numbers of clusters, and the value of k that maximizes this indicator was selected to continue the analysis.

Figure 5 – Average silhouette



Source: Authors (2026)

3.8. Final ranking of alternatives using the MABAC method

The final ranking of alternatives was performed using the MABAC Method. The alternatives were compared based on the border approximation area, defined as the geometric mean of the weighted values for each criterion: $gj = (\prod vij)\char`^(1/n)$. The overall performance of each alternative was calculated as the sum of the distances from each alternative to the border area: $Si = \Sigma\, wj\, rij$. The final ranking of the alternatives (Table 7) was obtained by ordering Si in descending order.

Table 7 – Final ranking of alternatives

Alternative	Si	Ranking
A6 Volocopter VoloCity	0.844	1st
A3 Vertical Aerospace VX4	0.699	2nd
A8 Eve Air Mobility EVE-100	0.662	3rd
A4 Beta Technologies ALIA-250	0.624	4th
A1 Archer Midnight	0.560	5th
A7 City Airbus NextGen	0.519	6th
A2 Joby S4	0.300	7th
A9 Jaunt Journey	0.262	8th
A5 Lilium Jet	0.230	9th
A10 EHang VT-30	0.172	10th

Source: Authors (2026)

4. Results and Discussion

The application of the MADRID Method made it possible to evaluate in a structured way the set of ten selected crewed eVTOL aircraft, integrating multiple technical, operational, environmental, and regulatory criteria relevant to the offshore context. The process resulted in a final multicriteria ranking obtained through the MABAC method, as well as in the identification of performance patterns through hierarchical clustering.

The results indicate that alternative A6 (Volocopter VoloCity) showed the best overall performance, ranking first overall. This result stems from its high level of redundancy in critical systems, regulatory maturity, and suitability for the offshore context, criteria that received high weights in the objective weighting stage (DIBR). Although it does not present the lowest cost or the greatest absolute range, its multicriteria balance proved superior when the operational and safety requirements typical of maritime environments were considered.

Alternatives A3 (Vertical Aerospace VX4) and A8 (Eve Air Mobility EVE-100) occupied the second and third positions, respectively. Both stood out for showing good performance in fundamental operational criteria such as range, payload capacity, and number of passengers, in addition to a satisfactory level of technological maturity. These results suggest that aircraft with greater operational capability, even when associated with higher costs, may present a strategic advantage when evaluated from a systemic perspective.

Alternatives such as A10 (EHang VT-30) and A5 (Lilium Jet) showed inferior performance in the final ranking. The result for the VT-30 is associated with limitations related to certification and suitability for the offshore environment, whereas the Lilium Jet was penalised because of high costs and greater operational complexity. These results show that technologically advanced solutions do not always translate into better strategic performance when analysed under multiple criteria.

The clustering analysis complements the multicriteria ranking by revealing similarity patterns among the alternatives. The dendrogram and silhouette index indicated the formation of two main clusters. The first cluster is composed of alternatives with high multicriteria performance, characterised by greater operational robustness, better regulatory adherence, and greater system reliability. The second cluster brings together alternatives with intermediate performance or lower alignment with the specific requirements of offshore operations.

The convergence between the clustering and MABAC ranking results reinforces the consistency of the analysis, since the alternatives positioned at the top of the ranking tend to belong to the higher-performance cluster. This methodological coherence demonstrates the ability of the MADRID Method to provide consistent support for both classification and ranking problems.

The obtained results suggest that eVTOL selection for offshore operations should prioritise criteria associated with safety, regulatory maturity, and system robustness, even at the expense of isolated economic or performance metrics. In highly operationally critical environments such as maritime platforms, systemic failures may entail significant risks, which justifies the greater importance assigned to non-financial criteria.

The study demonstrates that structured multicriteria approaches are suitable for supporting strategic decisions in innovation contexts, in which data are heterogeneous and incomplete. The integrated use of objective weighting, clustering, and multicriteria ranking proved effective for dealing with these characteristics.

Although a formal sensitivity analysis was not conducted, the convergence observed among the results of objective weighting, hierarchical clustering, and final ranking suggests structural stability of the obtained solution. Small variations in the weights of the most relevant criteria would tend to affect the intermediate ordering only marginally, without substantially altering the best-performing alternatives, which reinforces the conceptual robustness of the adopted approach.

5. Study Limitations

As study limitations, it is worth highlighting the dependence on public-domain technical data, which may change as certification programs and eVTOL technological development advance. In addition, the sector still faces relevant structural constraints, especially those related to the high cost of materials and the scarcity of specialised labour. These factors have already negatively affected some of the analysed companies (Lilium and Airbus), causing the interruption of studies and delays in aircraft certification processes, which reduces the number of manufacturers that are effectively consolidated and certified to sustain the continuity and scalability of Urban Air Mobility projects.

In this context, future studies may incorporate sensitivity analyses, prospective scenarios, and additional criteria, such as life-cycle costs, logistical impacts, and an expanded set of evaluated alternatives.

6. Final Considerations

This study demonstrated the applicability of the MADRID Method as a strategic decision-support framework for selecting crewed eVTOL aircraft for offshore operations, a context characterised by high operational criticality, strict regulatory constraints, and technological uncertainties. By integrating systemic problem structuring, objective weighting of criteria, clustering, and multicriteria ranking, the work shows the suitability of the method for non-compensatory decision problems associated with innovation.

The results showed that alternatives with greater regulatory maturity, redundancy of systems, and operational suitability for the maritime environment tend to present better overall performance, reinforcing the importance of a systemic evaluation that goes beyond isolated criteria of cost or range. The convergence between the results of the MABAC ranking and hierarchical clustering reinforces the internal consistency of the adopted approach.

From a methodological point of view, the study contributes by demonstrating the applicability of the MADRID Method in a new domain, distinct from previous applications, expanding its scope to the offshore sector and to Advanced Air Mobility. The use of objective data and the transparency of the analytical steps favour the reproducibility and adaptation of the model to other decision contexts.

From an academic point of view, the study contributes to the MCDA literature by expanding the domain of application of the MADRID Method and by demonstrating the feasibility of formal integration between Soft Systems Methodology and multicriteria methods in complex sociotechnical systems. From a managerial standpoint, the results offer analytical support for offshore operators, manufacturers, and regulators in the strategic evaluation of eVTOLs, highlighting the priority of safety, regulatory maturity, and systemic robustness criteria over isolated metrics of performance or cost.

The research demonstrates that the MADRID Method is an appropriate tool for supporting strategic decision-making in complex and innovative environments, offering consistent support for the transition of offshore operations toward safer, more efficient, and more sustainable aerial solutions.

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