Dutch Journal of Finance and Management
2024, 7(1), 26497
e-ISSN: 2542-4750
https://www.djfm-journal.com/
Research Article
OPEN ACCESS

Analytical Hierarchy Process for Risk Management in the Stabilized Flight Approach - Expert Judgment

Juan Carlos Pedroza [1], Alejandro Peña [1*], Lina Sepúlveda-Cano [1],
João Vidal Carvalho [2]

[1] School of Management, EAFIT University, Medellin, Colombia
[2] CEOS, Porto Accounting and Business School, Polytecnhic University of Porto, Portugal
*** Corresponding Author:** japena@eafit.edu.co

Citation: Pedroza, J. C., Peña, A., Sepúlveda-Cano, L., and Carvalho, J. V. (2024). Analytical Hierarchy Process for Risk Management in the Stabilized Flight Approach - Expert Judgment. *Dutch Journal of Finance and Management*, 7(1), 26497. https://doi.org/10.55267/djfm/14419

ARTICLE INFO

Received: 08 Feb 2024
Accepted: 26 Mar 2024

ABSTRACT

Destabilised approaches have been the primary cause of fatal accidents during the approach and landing phase, as stated in (Airbus, 2023). The stabilised approach concept is of great importance for the safe operation of an airline during the approach and landing phases (Acarbay & Kiyak, 2020). The elements highlighted in the approach phases are the runway's dry or contaminated condition and length. In the crew, we analyse their competence, recurrence, and fatigue. Another variable is the type of approach, whether it is precision, non-precision or visual. The external conditions of the aerodrome include obstacles, wind, and wildlife—the type of aircraft, whether light, medium or heavy. Due to the large amount of qualitative information derived from the pilots' experience about risk management in the approach and landing phases, this paper proposes an Analytic Hierarchy Process model (AHP) for threat characterisation and risk analysis to achieve a stabilised approach. The results show that AHP proposed model establishes a new methodology for identifying potential in-flight risks to air operations based on expert criteria, improving the decisions to land at an alternate airport based on qualitative information from expert pilots in the risk management field.

Keywords: Analytic Hierarchy Process, Approach Phase, Stabilised Approach, Qualitative Expert Opinion, Risk Management

INTRODUCTION

As mentioned by International Civil Aviation Organization (ICAO) (Doc 9859. Manual de gestión de la seguridad operacional, 2018), the safety of operations has a strategic objective that seeks to improve aviation safety globally, focusing primarily on its effective oversight by a state and its capabilities to manage the safety of operations. This objective is set in the context of the growing number of passenger and cargo movements and the need to address the sector's efficiency and environmental sustainability. The air transport industry is complex, and as described by (Acarbay & Kiyak, 2020), it comprises national and international activities such as passenger transport, cargo transport, alliances, commercial agreements, code-sharing, partnerships, and legal obligations. Standardisation of operations and compliance with rules and regulations are of great importance. Despite the complexity of the systems, airlines are expected to conduct their operations safely and securely within the framework of procedures and laws (Lee, 2023).

As stated (Gándara Martínez, 2022), one of the most relevant aspects of air operations is directly related to the profitability of airlines, as it is one of the most critical aspects; this is why the strategic growth of the sector is focused on carrying out flight operations safely while keeping them at low-risk levels. For this reason, aviation safety management is one of the essential components of airline administration, where airlines must follow multiple national and international standards for safe operation. These standards can be defined either by national civil aviation authorities or international organisations (Houwayji, 2024). The aviation industry entails a high degree of uncertainty as (Xin, et al., 2019) demonstrated, owing to organisational complexity, substantial capital investment, elevated operational risk, and the far-reaching consequences of an accident. Safety has emerged as a top priority for airlines (Bourjade & Muller-Vibes, 2023).

Consequently, risk assessment is evolving into the most valuable method for risk management. As highlighted by (Guo, et al., 2023), the damage incurred and the frequency of runway safety-related accidents significantly surpass those of other incidents. Runway-related accidents occur during the approach and landing phases, categorised into runway overruns, overshoots, tail strikes, and hard landings. Significantly, pilots experience peak workload during approaches and landings, especially in highly complex airport airspace. During this critical phase, pilots contend with numerous controllable factors, such as crew, Air Traffic Controllers (ATC), maintenance, aircraft, and ground support, alongside uncontrollable factors, including weather conditions and bird collisions (Boeing, 2014).

(Loukopoulos, et al., 2009) points out that even expert pilots make mistakes, which requires careful analysis of the nature of the tasks in the cockpit, the operational environment in which pilots work, the demands those tasks place on human cognitive processing and their vulnerability to characteristic forms of error in such situations. (Xin, et al., 2019) argue that, in recent years, a considerable amount of research has focused on solutions to this problem. Some studies have constructed different methods for making inferences under uncertainty, including the Analytic Hierarchy Process (AHP). It is a method used for decision-making by integrating expert judgment, making it ideal for decision-making without quantitative data (Petrillo, et al., 2023).

This paper presents a model inspired by the structure of a fuzzy AHP model for the analysis of the stabilised approach, which integrates qualitative information of in-flight operations based on pilot experts in risk management: runway, crew, type of approach, external conditions of the airport and type of aircraft are the criteria that allow modelling the risk of the approach and landing (Lakshmi & Udaya, 2024). According to the above, the AHP proposed model defines three scenarios or alternatives of operations: landing, not landing, holding on standby or proceeding to land at an alternative airport. The results produced by the AHP model allow the integration of a single structure of expert criteria to assess the risk in-flight operations comprehensively (Nuñez, et al., 2023), generating different recommendations for pilots to carry out takeoffs, stabilised approach and landing phase through the integration of risk management concepts, and their characterisation based on the experience of expert pilots, becoming the model as a reference model for the air transport industry in the risk management as a fundamental part of safe operation.

The rest of this paper is organised as follows: the second section presents the methodology used, while the third section presents the analysis and discussion of results. Finally, the section on conclusions and future work is presented.

MATERIALS AND METHODS

Materials

For the analysis of the risk during the approach and landing phase in aeronautical accidents, and by the literature review, the variables that have a determining impact on the safety of this part of the flight were identified: runway, crew, type of approach, external conditions of the aerodrome and type of aircraft (Bernsmed, et al., 2022). For Configuring the AHP proposed model, the variables mentioned above were analysed by four (4) pilot experts in the aeronautical sector (instructor pilots), based on risk management criteria in a stabilised approach scenario, to finally establish a series of alternatives to achieve a safe air operation (Muecklich, et al., 2023).

In the context of different airports in Colombia, such as El Dorado (SKBO) in the city of Bogotá, Olaya Herrera (SKMD) in Medellín Antioquia, Matecaña (SKPE) in the city of Periera, a structured interview was conducted to obtain relevant qualitative information from experts based on the criteria that characterise the stabilised approach at each of these airports. The first analysis criterion focused on runway characterisation. According to (Milbredt, et al., 2022), airports should be designed to avoid internal and external risks; however, events such as a wet or contaminated runway, its length, and possible obstacles on the approach represent a challenge in risk management. The second criterion to be taken into account focuses on the crew, as mentioned by (Muñoz-Marrón, 2018); since the focus is no longer on the pilot (as in the first generation training), on the crew (typical of the second and later generations), on the training and specific use of automation, or on the leadership role of aircraft commanders (highlighted in the third generation), not even on the error management approach (of the fifth generation), but on threat and safety management, covering a much broader scope, that in which air operations take place. For this reason, competencies, recurrence, and fatigue are also analysed, which, according to (Taneja, 2007), is determined by the loss of sleep and the decrease of circadian rhythm in aircrews, affecting flight safety.

The third and fourth criteria determined by the experts were the type of approach and the external conditions of the aerodrome, respectively. In contrast, the fifth criterion is based on PBN (Performance-Based Navigation) (Pamplona, et al., 2021), which varies according to aircraft type and individual route characteristics (Liu, et al., 2024). In the latter criterion, consideration was given to whether the aircraft is heavy, medium, or light, which must be considered for achieving the runway and approach.

Methods

AHP Model

According to (Toskano Hurtado, 2005), AHP refers to ordering the priorities of importance and what is preferred or its probability depending on the attribute that, according to our criteria, would be shown in the decision hierarchy in pairs. He also mentions that with the AHP model, we would have the possibility to analyse the reciprocal relationship when comparing the elements with the help of a group of experts (Petrillo, et al., 2023). Afterwards, we take the average of the opinions; using the individual opinion and the group agreement, we obtain the hierarchy, and the model will combine the results obtained by geometric averaging in the matrices. Then, we take a geometric average, a task to be performed by each expert member of the group; the AHP combines the geometric average results. The basic principles behind AHP, according to (Coyle, 2004), are: first, decision-makers assign numerical values to indicate the importance of one attribute over another based on a scale developed by Saaty (1987), as shown in **Table 1.**

Table 1. The fundamental scale (Saaty, 1987)

Intensity of importance on an absolute scale	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Moderate importance of one over another	Experience and judgment strongly favor one activity over another
5	Essential or strong importance	Experience and judgment strongly favor one activity over another
7	Very strong importance	An activity is strongly favored, and its dominance demonstrated in practice
9	Extreme importance	The evidence factoring one activity over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed
Reciprocals	If activity i has one of the above numbers assigned to it when compared with activity j, then j has the reciprocal value when compared with i	
Rationals	Ratios arising from the scale	If consistency were to be forced by obtaining n numerical values to span the matrix

Second, the pairwise comparisons are used to create the matrix $\mathbf{A} \in R^{n\times n}$ as in Eq. (1)

$$\boldsymbol{A} = \begin{bmatrix} 1 & a_{12} & \cdots & a_{1n} \\ a_{21} & 1 & \dots & a_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ a_{n1} & a_{n2} & \dots & 1 \end{bmatrix}, \quad (1)$$

where $a_{ij} = 1/a_{ji}$ is the measure of the relative weight of the criterion in the row i when compared to the criterion in the column j, and n is the criteria number. A similar matrix can be used for alternatives on the same criterion (called priority matrix, $\boldsymbol{P} \in R^{m\times m}$), i.e. a criterion can have m states or alternatives, which can be scored according to the decision-maker's preferences.

Normalization

A normalised version of Eq. (1) can be computed as in (Harjanto, et al., 2021) by dividing the value of each element of matrix A (or P for the alternatives case) by the row sum to which it belongs so that the vector of weights ($\boldsymbol{W} = [w_1, w_2, \dots, w_n]^\top$) of each criterion is obtained from the average of the elements of each row of the normalised matrix. The normalised matrix, $\boldsymbol{N}$, is shown in Eq. (2)

$$\boldsymbol{N} = \begin{bmatrix} \frac{1}{\sum_i a_{i1}} & \frac{a_{12}}{\sum_i a_{i2}} & \cdots & \frac{a_{1n}}{\sum_i a_{in}} \\ \frac{a_{21}}{\sum_i a_{i1}} & \frac{1}{\sum_i a_{i2}} & \cdots & \frac{a_{2n}}{\sum_i a_{in}} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{a_{n1}}{\sum_i a_{i1}} & \frac{a_{n2}}{\sum_i a_{i2}} & \cdots & \frac{1}{\sum_i a_{in}} \end{bmatrix} = \begin{bmatrix} n_{11} & n_{12} & \dots & n_{1n} \\ n_{21} & n_{22} & \dots & n_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ n_{n1} & n_{n2} & \dots & n_{nn} \end{bmatrix}, \tag{2}$$

with $i = 1,2, \dots, n$.

Weight Criteria

Once the matrix $\boldsymbol{N}$ is obtained, the weight for each criterion (or for each alternative) could be calculated by adding the elements of the i-th row and dividing the sum by the criteria number, as in Eq. (3)

$$\boldsymbol{W} = \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} \frac{\sum_j n_{1j}}{n} \\ \frac{\sum_j n_{2j}}{n} \\ \vdots \\ \frac{\sum_j n_{nj}}{n} \end{bmatrix}, \tag{3}$$

with w_i the weight of the criterion i.

Global Priority Matrix

Each decision alternative is condensed into a column vector to consolidate the comprehensive priority scale. This vector is derived from the product of a matrix formed by the alternatives' weight vectors and the criteria' weight vectors, as outlined below (Eq. (4)):

$$\boldsymbol{GP} = \begin{bmatrix} gp_1 \\ gp_2 \\ \vdots \\ gp_m \end{bmatrix} = (\boldsymbol{WP})(\boldsymbol{W}) = \begin{bmatrix} wp_{11} & wp_{12} & \dots & wp_{1n} \\ wp_{21} & wp_{22} & \dots & wp_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ wp_{m1} & wp_{m2} & \dots & wp_{mn} \end{bmatrix} \begin{bmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{bmatrix}, \tag{4}$$

where gp_i is the overall priority (concerning the overall target) of alternative i ($i = 1, 2, \dots, m$), and wp_{ij} is the weighting of alternative i for criterion j.

Metrics

Based on (Nguyen, 2014), a decision-maker is consistent if the matrix $\boldsymbol{A}$ satisfies $a_{ik} = a_{ij}a_{jk}$ for $i, j, k = 1, \dots, n$; then, the ij of $\boldsymbol{A}$ can be written as Eq. (5)

$$a_{ij} = \frac{w_i}{w_j}, \tag{5}$$

with w_i, w_j the weight of criteria i and j, respectively.

More compactly, we say that $\boldsymbol{A}$ (Eq. (1)) is consistent if and only if $\boldsymbol{AW} = n\boldsymbol{W}$. Being λ_{max} the principal eigenvalue of $\boldsymbol{A}$, according to (Pant, et al., 2022), the value of λ_{max} can never be less than n, and when $\lambda_{max} = n$, it is said that $\boldsymbol{A}$ satisfies the consistency property, then $\boldsymbol{AW} = \lambda_{max}\boldsymbol{W}$.

As a measure of inconsistency, (Saaty, 1987) introduced the CI (Consistency Index), as in Eq. (6)

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

A scaled version of the CI is the Consistency Ratio, CR, expressed as the Consistency Index of A over a Random Consistency Index, RI (see **Table 2**), as in Eq. (7)

$$CR = \frac{CI}{RI}. \quad (7)$$

Table 2. Random Index (Saaty, 1987)

n	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
RI	0.00	0.00	0.58	0.90	1.12	1.24	1.32	1.41	1.45	1.49	1.51	1.48	1.56	1.57	1.58

Hurtado (Toskano Hurtado, 2005) states that CR values above 0.10 indicate inconsistent judgements. Therefore, the expert will likely want to reconsider and change the original values of the paired comparisons matrix. It is suggested that CR figures of 0.10 or less indicate a reasonable level of consistency in paired comparisons.

RESULTS AND DISCUSSION

According to the structure of the AHP method, four stages were considered (Madzík & Falát, 2022). In the first stage, an extensive literature review was carried out to identify the development trends in this area of knowledge regarding the integration of qualitative information from experts for decision-making in the aeronautical field.

In the second stage, the objectives were identified during the stabilized approach phase of the flight and a series of structured interviews with experts in the field concerning the characterization of criteria and alternatives, as in **Figure 1**.

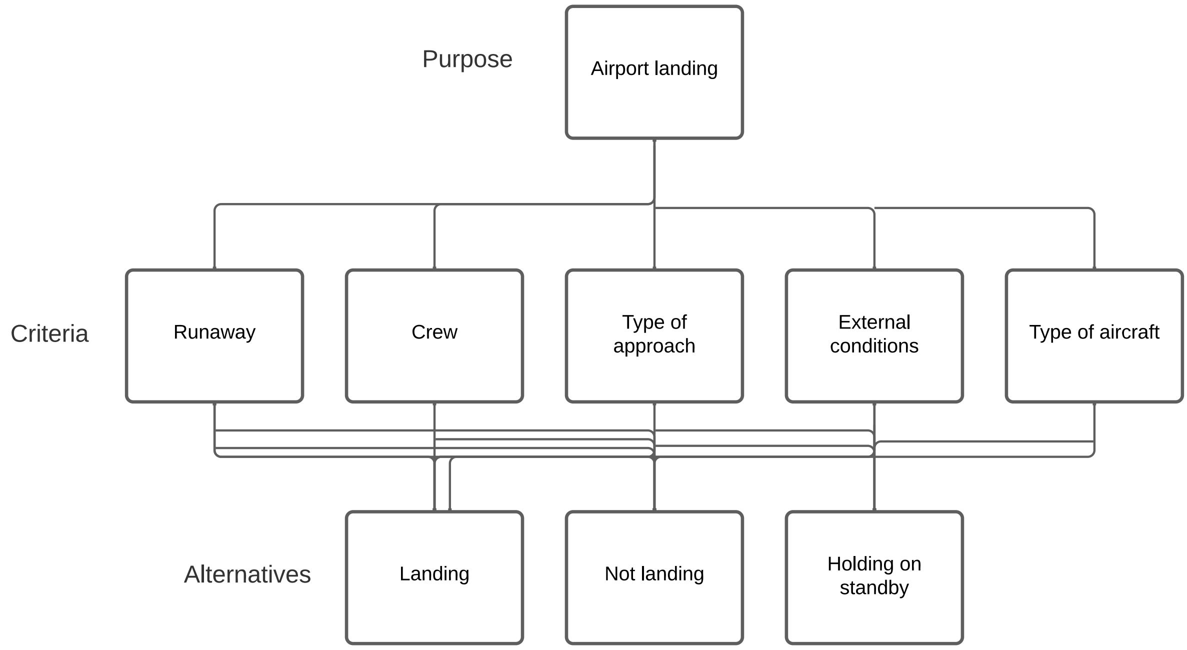

Figure 1. Setting criteria and alternatives for safe landing

The above matrices for AHP were constructed, which allowed the criteria to be characterised according to the qualitative information from experts (**Table 3**).

Table 3. Criteria characterisation by experts

Alternatives \ Criteria	Runaway	Crew fatigue	Type of approach	External conditions	Type of aircraft
Landing	Completely wet	Low	Visual	Typical	Medium
Not landing (landing in alternative airport)	Dry	Medium	Precision	Poor	Medium
Holding on standby	Completely wet	Medium	Visual	Typical	Medium

Table 3 shows the qualitative relationship of the scenarios that comprise the approach phase concerning the decision criteria. Here, the importance of the criteria can be seen according to each of the alternatives. According to the expert criteria, the first alternative shows that the runway has adverse conditions and that the crew is in its first hours of service. In this alternative, the visual approach predominates over external conditions characterised by natural obstacles, mountains, and a medium-category aircraft. According to the experts' criteria, the conditions for the alternate landing show favourable criteria for the approach phase as opposed to the landing in adverse conditions, which once again validates the integration of qualitative information from experts concerning the characterisation of the stabilised approach..

In this same stage, each scenario or alternative was determined by comparing the criteria according to the Saaty scale. Eq. (8) shows the pairwise comparisons matrix.

$$\boldsymbol{A} = \begin{matrix} \\ R \\ CF \\ TA \\ EC \\ AC \end{matrix} \begin{bmatrix} \text{R} & \text{CF} & \text{TA} & \text{EC} & AC \\ 1 & 4 & 4 & 0.17 & 4 \\ 0.25 & 1 & 4 & 0.25 & 2 \\ 0.25 & 0.25 & 1 & 0.25 & 3 \\ 6 & 4 & 4 & 1 & 6 \\ 0.25 & 0.25 & 0.33 & 0.17 & 1 \end{bmatrix}, \tag{8}$$

where R: Runaway, CF: Crew Fatigue, TA: Type of Approach, EC: External Conditions, AC: Type of Aircraft.

In the third stage, the normalised matrix $\boldsymbol{N}$ (see Eq. (9)), the weighting $\boldsymbol{W}$, and the percentage value of the criteria comparison matrix were obtained $\boldsymbol{W}\%$ (see Eq. (10)).

$$\boldsymbol{N} = \begin{matrix} \\ R \\ CF \\ TA \\ EC \\ AC \end{matrix} \begin{bmatrix} \text{R} & \text{CF} & \text{TA} & \text{EC} & AC \\ 0.13 & 0.41 & 0.30 & 0.09 & 0.25 \\ 0.03 & 0.10 & 0.30 & 0.14 & 0.13 \\ 0.03 & 0.03 & 0.08 & 0.14 & 0.19 \\ 0.77 & 0.41 & 0.30 & 0.55 & 0.38 \\ 0.03 & 0.05 & 0.03 & 0.09 & 0.06 \end{bmatrix}, \tag{9}$$

$$\boldsymbol{W} = \begin{matrix} R \\ CF \\ TA \\ EC \\ AC \end{matrix} \begin{bmatrix} 0.24 \\ 0.14 \\ 0.09 \\ 0.48 \\ 0.05 \end{bmatrix} \qquad \boldsymbol{W}\% = \begin{matrix} R \\ CF \\ TA \\ EC \\ AC \end{matrix} \begin{bmatrix} 24\% \\ 14\% \\ 9\% \\ 48\% \\ 5\% \end{bmatrix} \tag{10}$$

The normalised matrix is evaluated in this stage using the random Consistency Index (CI). Eq. (9) shows the structure of the criteria comparison matrix according to the Saaty scale (Peña , et al., 2018). In this matrix, the criteria were ranked from lowest to highest according to the importance of each one of them according to the scenarios presented in **Table 3**. As can be seen, the External Conditions criterion stands out as the most important criterion, as shown by its dominance ratio to the runway, the Crew, the Type of Approach (4), and the Type of Aircraft. One of the criteria with lower importance was the Aircraft Type criterion, which had values below unity and the main diagonal or dominance zone of the criteria comparison matrix.

In the final stage, we selected criteria and safe landing alternatives, giving a hierarchy to the alternatives versus landing, performing a standby manoeuvre (Boeing, 2014), or landing at an alternate airport. It is essential to remember that for this stage, the airports of Medellín (EM-Olaya Herrera), Bogotá (BOG), and Pereira were evaluated for landing as reference airports for air operations in Colombia.

Table 4 shows the characterisation of each of the alternatives compared to each criterion. Each matrix last row shows each criterion's normalised average against each alternative. Here, the highest value determines the most important alternative concerning the criteria. The most favourable alternative for the Runaway criterion (R) and External Conditions (EC) is to land at an alternate airport (0.643388). For the Crew Fatigue (CF), the most relevant alternative is Landing at the Destination with a value of 0.714285, while for the Type of Approach (TA), Landing and Holding had the same value. Finally, the three alternatives had the same value for the Type of Aircraft (AC) because they are the same aircraft.

Table 4. Characterisation of each of the alternatives compared concerning each of the criteria. **P** is the priority matrix, **NP** is the normalised priority matrix, **WP** is the weight of each alternative in the criterion, and **WP**% is the percentual version of **WP**

Criteria	**P**				**NP**			**WP**	**WP%**
	Alternative	Landing	Not landing	Holding on standby					
	Landing	1	0.3333	5	0.238	0.2258	0.3846	0.8485	0.2828333
R	Not landing	3	1	7	0.714	0.6774	0.5385	1.9302	0.6434
	Holding on standby	0.2	0.14	1	0.047	0.0968	0.0769	0.2213	0.0737666
	Total	4.2	1.4733	13	1	1	1	3	1
Criteria	P				NP			WP	WP%
	Alternative	Landing	Not landing	Holding on standby					
	Landing	1	5	5	0.7142	0.7142	0.7142	2.1426	0.7142
CF	Not landing	0.2	1	1	0.1429	0.1429	0.1429	0.4287	0.1429
	Holding on standby	0.2	1	1	0.1429	0.1429	0.1429	0.4287	0.1429
	Total	1.4	7	7	1	1	1	3	1
Criteria	**P**				**NP**			**WP**	**WP%**
	Alternative	Landing	Not landing	Holding on standby					
	Landing	1	7	1	0.4667	0.4667	0.4667	1.4001	0.4667
TA	Not landing	0.14285714	1	0.142857143	0.0666	0.0666	0.0666	0.1998	0.0666
	Holding on standby	1	7	1	0.4667	0.4667	0.4667	1.4001	0.4667
	Total	2.14285714	15	2.142857143	1	1	1	3	1
Criteria	**P**				**NP**			**WP**	**WP%**
	Alternative	Landing	Not landing	Holding on standby					
	Landing	1	0.14285714	1	0.1111	0.1111	0.1111	0.333	0.1111
EC	Not landing	7	1	7	0.7779	0.7779	0.7779	2.334	0.7779
	Holding on standby	1	0	1	0.1111	0.1111	0.1111	0.333	0.1111
	Total	9	1.14285714	9	1	1	1	3	1
Criteria	**P**				**NP**			**WP**	**WP%**
	Alternative	Landing	Not landing	Holding on standby					
	Landing	1	1	1	0.3333	0.3333	0.3333	1.000	0.3333
AC	Not landing	1	1	1	0.3333	0.3333	0.3333	1.000	0.3333
	Holding on standby	1	1	1	0.3333	0.3333	0.3333	1.000	0.3333
	Total	3	3	3	1	1	1	3	1

With the information obtained in **Table 4** we calculate the Global Priority Matrix, GP (Eq. (11))

$$\boldsymbol{GP} = \begin{matrix} Landing \\ Not\ landing \\ Holding\ on \end{matrix} \begin{bmatrix} \text{R} & \text{CF} & \text{TA} & \text{EC} & AC \\ 0.2829 & 0.7142 & 0.4667 & 0.1111 & 0.333 \\ 0.6434 & 0.1428 & 0.0666 & 0.7778 & 0.333 \\ 0.0737 & 0.1458 & 0.4667 & 0.1111 & 0.333 \end{bmatrix} \begin{bmatrix} 0.24 \\ 0.14 \\ 0.09 \\ 0.48 \\ 0.05 \end{bmatrix} = \begin{bmatrix} 0.2797 \\ 0.5694 \\ 01508 \end{bmatrix} \quad (11)$$

According to the results, the percentage of prioritisation obtained recommends landing at the alternate airport in the city of Pereira with a value of 57%, compared to 28% for landing at the destination airport, with 15% for holding on standby.

CONCLUSIONS

The AHP method allowed the characterisation of the stabilised landing approach according to expert judgement and contributed decisively to improving safety by integrating qualitative information and risk management concepts. As mentioned by the (Federal Aviation Administration FAA, 2009), and according to statistics from the National Transportation Safety Board (NTSB), in the last 20 years, approximately 85% of aviation accidents have been caused by "pilot error", mainly because flight instructors focus the training of new pilots on physical and quantitative aspects of the aircraft, leaving aside qualitative aspects that are relevant to the management of risks in flight. For this reason, the proposed model is configured as a reference model for pilot training on risk management during take-off, approach, and landing.

The AHP method allowed a structured way to integrate the expert criteria as qualitative information for decision-making in the stabilised approach phase. It is essential to highlight that the qualitative criteria that the AHP method integrates were selected from the literature review in this area of knowledge. This information also made it possible to identify the best alternative based on expert criteria to establish safe alternatives for risk management in air operations. Due to its flexible structure, the AHP method can be applied to the stabilised approach for airports in national or international scenarios; this is how the model manages to extract the most relevant criteria in the process of the approach phase, and from the matrices it uses the ethical information of the experts to finally have the safe answer of landing, not landing, holding at the holding point or going to the alternative airport.

The future studies that are evident to work on are analysing the other phases of the flight and integrating strategic risks into the decision-making process by the participating experts. For the characterisation of the criteria that make up the model, in the criteria where consensus was not reached among the experts, it is essential to perform a sensitivity analysis to assess the extent to which divergent judgements lead to significantly different results.

REFERENCES

Acarbay, C. & Kiyak, E. (2020). Risk mitigation in unstabilized approach with fuzzy Bayesian bow-tie analysis. Aircraft Engineering and Aerospace Technology.

Airbus (2023). Airbus Safety First. [Online] Available at: https://safetyfirst.airbus.com/prevention-of-unstable-approaches/[Accessed 06 12 2023].

Bernsmed, K., Bour, G., Lundgren, M. & Bergstrom, E. (2022). An evaluation of practitioners' perceptions of a security risk assessment methodology in air traffic management projects. Journal of Air Transport Management, Volume 102, p. 102223.

Boeing (2014). Why and When to Perform a Go-Around Maneuver, s.l.: Boeing.

Bourjade, S. & Muller-Vibes, C. (2023). Optimal leasing and airlines' cost efficiency: A stochastic frontier analysis. Journal of Air Transport Management, Volume 176, p. 103804.

Coyle, G. (2004). Practical Strategy: AHP. s.l.:Pearson Education Limited.

Federal Aviation Administration FAA (2009). Risk Management Hand Book. FAA-H-8083-2, s.l.: FAA.

Gándara Martínez, J. (2022). Revolución en los cielos. Segunda ed. s.l.:Profit.

Guo, Y. et al. (2023). Deep-Learning-Based Model for Accident-Type Prediction During Approach and Landing. IEEE Transactions on Aerospace and Electronic Systems, 59(1), pp. 472-482.

Harjanto, S., Setiyowati & Vulandari, R. T. (2021). Application of Analytic Hierarchy Process and Weighted Product Methods in Determining the Best Employees. Indonesian Journal of Applied Statistics, 4(2), pp. 103-112.

Houwayji, S. (2024). The Influence of Risk Management Practices on Financial Market Stability: Insights from Lebanon. Dutch Journal of Finance and Management, 7(1), p. 25671.

International Civil Aviation Organization (ICAO) (2018). Doc 9859. Manual de gestión de la seguridad operacional, Quebec: ICAO.

Lakshmi, V. & Udaya, K. (2024). A novel randomized weighted fuzzy AHP by using modified normalization with the TOPSIS for optimal stock portfolio selection model integrated with an effective sensitive analysis. Expert Systems with Applications, Volume 243, p. 122770.

Lee, K. (2023). Airline operational disruptions and loss-reduction investment. Transportation Research Part B: Methodological, Volume 177, p. 102817.

Liu, W. et al. (2024). Comparison of performance between PMS and trombone arrival route topologies in terminal maneuvering area. Journal of Air Transport Management, Volume 115, p. 102532.

Loukopoulos, L. D., Dismukes, R. K. & Barshi, I. (2009). The Multitasking Myth: Handling Complexity in Real-World Operations. s.l.:Routledge.

Madzík, P. & Falát, L. (2022). State-of-the-art on analytic hierarchy process in the last 40 years: Literature review based on Latent Dirichlet Allocation topic modelling.. PLoS One, 17(5).

Milbredt, O., Popa, A., Doenitz, F.-C. & Hellman, M. (2022). Aviation security automation: The current level of security automation and its impact. Journal of Airport Management, 16(2), pp. 184-208.

Muecklich, N., Sikora, I., Paraskevas, A. & Padhra, A. (2023). Safety and reliability in aviation – A systematic scoping review of normal accident theory, high-reliability theory, and resilience engineering in aviation. Safety Science, Volume 162, p. 106097.

Muñoz-Marrón, D. (2018). Human Factors in Aviation: CRM (Crew Resource Management). Papeles del Psicólogo / Psychologist Papers, 39(3), pp. 191-199.

Nguyen, G. H. (2014). The Analytic Hierarchy Process: A Mathematical Model for Decision Making Problems. Wooster: The College of Wooster Libraries.

Nuñez, M. et al. (2023). Risk governance in the textile/clothing industry: A case study in medium enterprises. Dutch Journal of Finance and Management,, 6(2), p. 25191.

Pamplona, D. A., de Barros, A. G. & Alves, C. J. (2021). Performance-Based Navigation Flight Path Analysis Using Fast-Time Simulation. Energies, 14(22).

Pant, S. et al. (2022). Consistency Indices in Analytic Hierarchy Process: A Review. Mathematics, 10(8).

Peña , P. et al. (2018). A fuzzy ELECTRE structure methodology to assess big data maturity in healthcare SMEs. Soft Computing, 23(20), pp. 10537-10550.

Petrillo, A., Pamplona, V. & Tramarico, C. (2023). State-of-the-Art Review on the Analytic Hierarchy Process with Benefits, Opportunities, Costs, and Risks. J. Risk Financial Manag, 16(8), p. 372.

Saaty, R. W. (1987). The analytic hierarchy process—what it is and how it is used. Mathematical Modelling, 9(3-5), pp. 161-176.

Taneja, N. (2007). Fatigue in Aviation: A Survey of the Awareness and Attitudes of Indian Air Force Pilots. The International Journal of Aviation Psychology, pp. 275-284.

Toskano Hurtado, G. B. (2005). Universidad Nacional Mayor de San Marcos. [Online] Available at: https://sisbib.unmsm.edu.pe/bibvirtualdata/tesis/basic/toskano_hg/toskano_hg.pdf [Accessed 06 12 2023].

Xin, F., Jun-Cheng, J., Jun-Qiang, L. & Yue-Gui, F. (2019). Airline safety assessment based on fuzzy mathematics and Bayesian networks. Journal of Intelligent & Fuzzy Systems, 37(6), pp. 8577-8587.