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A Fuzzy TOPSIS Based Model for Safety Risk Assessment of Operational Flight Data

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***Abstract*—**Flight Data Monitoring (FDM) program assists an operator in aviation industries to identify, quantify, assess and address operational safety risks, in order to improve safety of flight operations. FDM is a powerful tool for an aircraft operator integrated into the operator's Safety Management System (SMS), allowing to detect, confirm, and assess safety issues and to check the effectiveness of corrective actions, associated with human errors. This article proposes a model for safety risk assessment level of flight data in a different aspect of event focus based on fuzzy set values. It permits to evaluate the operational safety level from the point of view of flight activities. The main advantages of this method are proposed qualitative safety analysis of flight data. This research applies the opinions of the aviation experts through a number of questionnaires Related to flight data in four categories of occurrence that can take place during an accident or an incident such as: Runway Excursions (RE), Controlled Flight Into Terrain (CFIT), Mid-Air Collision (MAC), Loss of Control in Flight (LOC-I). By weighting each one (by F-TOPSIS) and applying it to the number of risks of the event, the safety risk of each related events can be obtained.

***Keywords*—**F-TOPSIS, fuzzy set, FDM, flight safety.

I. Introduction

LIFE management and monitoring of aircraft performance are critical issues at the middle and later stages of aircraft life, so it is necessary to manage risk of structural fatigue failure [1].

FDM: It is the systematic, pro-active use of digital flight data from routine operations to improve aviation safety within an intrinsically non-punitive and just safety culture. By using FDM system, operator can make a comparison their Standard Operating Procedures (SOPs) with Pilot's flight activities.

A. Flight Data Analysis

Annex 6, Part I, defines "flight data analysis" as a process of analyzing recorded flight data in order to improve the safety of flight operations [2]. Flight data analysis programmers (FDAPs) offer a wide spectrum of applications for safety management. Furthermore, it also offers the benefit of improving operational efficiency and economy that compensate the needed investment. The objective is to:

- Determine operating norms;
- Identify potential and actual hazards in operating procedures, fleets, aerodromes, ATC procedures;
- Identify trends;
- Monitor the effectiveness of corrective actions taken;
- Provide data to conduct cost-benefit analyses;
- Optimize training procedures;
- Provide actual rather than presumed performance measurement for risk management purposes [3].

B. FDM Programmers

Historically the principal purpose of Flight Data Recorders (FDR) was to assist accident investigators to determine the cause of air crashes. With the purpose of better understanding of serious incident, analyzing of the FDR is useful tool [4]. FDM program assists an operator to identify, quantify, assess and address operational risks [6] which aims to improve aviation safety by collecting and analyzing digital flight data. It has now become one of the major resources of operational performance measurement and a key component of SMS [5]. Analysis shows that FDM has great potential as an anticipatory tool for investigating root causes and risk levels associated with human errors, allowing pro-active early identification of human factors risks.

This article will take aim to set a new approach for assessment of safety risk of flight data based on the Fuzzy TOPSIS method which composes criteria and indexes. Multi-attribute decision-making (in conjunction with application of fuzzy numbers) are used for determination of significance for each criterion and indexes. So, these criteria will collectively form a numerical priority with the aid of F-TOPSIS (to precisely make realistic comparisons and inference of each factor and indexes). Then, safety risk of each index is assessed by using weighting of factor and indexes.

II. Research Literature

A. The FDM Process

The FDM process is an iterative process that exists on a continuum, where each activity will likely be occurring simultaneously. Six basic steps, or stages, are proposed as in Fig. 1.

1. Data Acquisition
2. Data Recording & Storage
3. Data Transmission (or Retrieval)
4. Data Analysis
5. Information Reporting
6. Operator's Flight Safety Program

We define each step as:

1. Data Acquisition

In Data Acquisition, the data acquisition unit (DAU) collects a large amount of data related to the aircraft's

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operations.

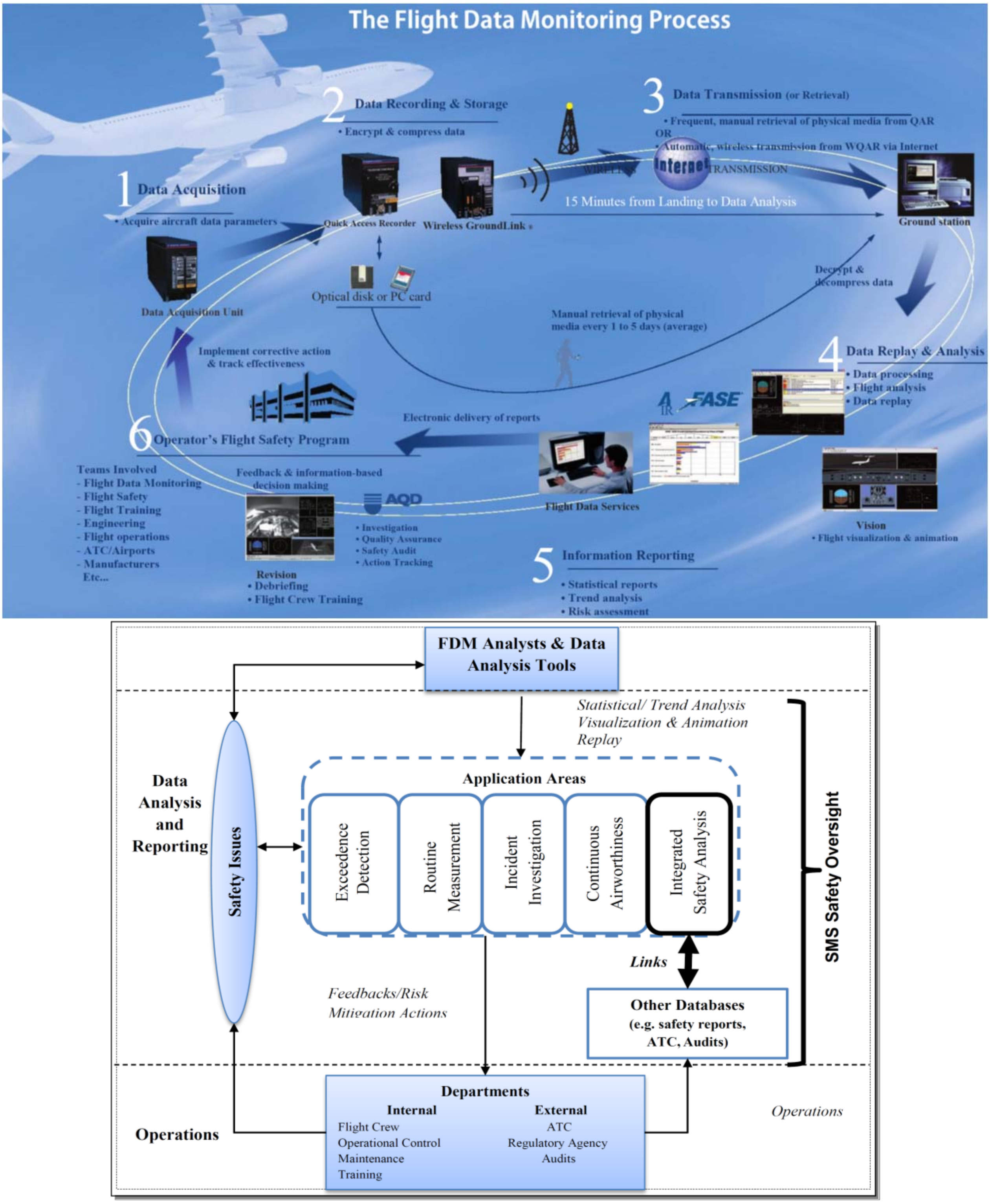


Fig. 1 FDM process

2. Data Recording & Storage

In the Data Recording & Storage stage of the FDM process, the flight data that were acquired with the DAU are sent to a device where it is recorded and stored on the aircraft.

3. Data Transmission (or Retrieval)

This step intends to transfer flight data from recording device to an analysis facility.

4. Data Analysis

Some aircrafts already routinely record large quantities of flight data, but recording data is not enough. In order to be effective as a tool to improve operational efficiency, an operator must be committed to the routine analysis of its flight data. The primary goal of the Data Analysis step is to identify any events or deviations from pre-defined criteria ("exceedances") that may have occurred during flight. These criteria, which may be operational or maintenance-related, are determined by reference to the various operational manuals and will be tailored to the individual operator's requirements. Since there can be over 100 such events defined by an operator that must be checked for every flight, automated computer processing of data is essential.

5. Information Reporting

Data analysis is incomplete without the generation of summary reports. Data by itself is only so helpful; turning data into information is where the real value resides for airlines.

In the Information Reporting stage of FDM, trained, qualified flight analysts and computer literate personnel use the analysis software to generate easy to understand information reports that yield statistical information, trend analysis, and risk assessment on a routine, periodic basis. If a third party has done the analysis and reporting, the information reports are easily sent electronically to the operator to assist them in interpreting flight data.

6. Operator's Flight Safety Program

The receipt of the information reports by the operator's Flight Safety Program is not the final stage in the FDM process, but it is a critical one, as the reports empower the operator by giving it the necessary information to improve the overall operational maintenance and safety of their aircraft.

A FDM team comprised of various flight safety staff, analysts and working groups, can now review key issues and events, confirm their validity, and further investigate the circumstances behind events if necessary. In certain circumstances, the involvement of the pilot in command of the aircraft at the time of the event may aid understanding, so operators will usually have agreements in place to allow this. The most effective programs have been shown to exist within an open, non-punitive reporting culture that encourages participation in FDM without fear of recrimination. This approach ensures full participation of pilots and others within the organization.

With verified objective information, an operator now has the ability to provide meaningful feedback and make information-based decisions that affect critical areas within the organization such as flight safety, maintenance, engineering, flight operations, flight training, as well as to function outside the organization such as air traffic control/ airports, and manufacturers. It is also equipped to implement preventative and corrective actions, and to track the ongoing effectiveness of these actions.

The FDM system should be constructed to identify areas of operational risk and quantify current safety margins and changing operational risks by highlighting when non-standard, unusual, or unsafe circumstances occur. By assessment of the risk, it must be determined which may become unacceptable if the discovered trend continues. In accordance with such assessment, remedial action must be provided for unacceptable risk, and the effectiveness of any remedial actions was confirmed by continued monitoring.

Based on: The ICAO Annex 6 Pt 1 recommended practice, AAR-OPS 1.037 states that: "an operator shall establish an accident prevention and flight safety programme, which may be integrated with the Quality System, including programs to achieve and maintain risk awareness by all persons involved in operations". ICAO Doc 9422 (Accident Prevention Manual) gives appropriate guidance material and describes a risk management process that forms the basis of an operator's SMS.

Under ICAO Annex 6 Part 1 (Amendment), flight data analysis is mandatory for operators of aeroplanes of a certified take-off mass in excess of 27,000 kg. In the UK, guidance on the implementation of this directive is provided by the Civil Aviation Authority (CAA) in document CAP 739. Other nations have similar guidance, but the development of FDM has been pioneered by the CAA since the 1970s in conjunction with a major UK airline. The CAA suggests that FDM should form part of a feedback loop, preferably as part of a SMS. FDM is part of a broader safety culture in which the flight crew is encouraged to report operational issues, events and potential problems [16].

By integration of FDM within risk management system, FDM program should be more effective tool for airline management. Safety risk assessment has key component as SMS from a hazard identification or situation. Some definitions used in this area are as follows :

Safety risk probability: Safety risk probability is defined as the likelihood or frequency that a safety consequence or outcome might occur [17].

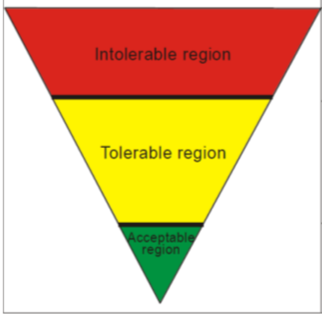
Safety risk severity: is the amount of damage or harm that a hazard could create and is ranked on a five point scale as: Catastrophic, Hazardous, Major, Minor, Negligible [17].

Safety risk tolerability: The safety risk probability and severity assessment process can be used to derive a safety risk index. The index created through the methodology described above consists of an alphanumeric designator, indicating the combined results of the probability and severity assessments. The respective severity/probability combinations are presented in the safety risk assessment matrix in Fig. 2 [17].

The third step in the process is to determine safety risk tolerability. First, it is necessary to obtain the indices in the safety risk assessment matrix. For example, consider a situation where a safety risk probability has been assessed as occasional (4), and safety risk severity has been assessed as hazardous (B). The composite of probability and severity (4B) is the safety risk index of the consequence.

Safety risk management encompasses the assessment and mitigation of safety risks.

Risk probability		Risk severity				
		Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent	5	5A	5B	5C	5D	5E
Occasional	4	4A	4B	4C	4D	4E
Remote	3	3A	3B	3C	3D	3E
Improbable	2	2A	2B	2C	2D	2E
Extremely improbable	1	1A	1B	1C	1D	1E



Tolerability description	Assessed risk index	Suggested criteria
Intolerable region	5A, 5B, 5C, 4A, 4B, 3A	Unacceptable under the existing circumstances
Tolerable region	5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A	Acceptable based on risk mitigation. It may require management decision.
Acceptable region	3E, 2D, 2E, 1B, 1C, 1D, 1E	Acceptable

Fig. 2 Safety risk assessment matrix

Risk index range	Description	Recommended action
5A, 5B, 5C, 4A, 4B, 3A	High risk	Cease or cut back operation promptly if necessary. Perform priority risk mitigation to ensure that additional or enhanced preventive controls are put in place to bring down the risk index to the moderate or low range.
5D, 5E, 4C, 4D, 4E, 3B, 3C, 3D, 2A, 2B, 2C, 1A	Moderate risk	Schedule performance of a safety assessment to bring down the risk index to the low range if viable.
3E, 2D, 2E, 1B, 1C, 1D, 1E	Low risk	Acceptable as is. No further risk mitigation required.

Fig. 3 Safety risk tolerability matrix

Safety risks assessed in the tolerable region are acceptable provided that appropriate mitigation strategies are implemented by the organization. A safety risk initially assessed as intolerable may be mitigated and subsequently moved into the tolerable region provided that such risks remain controlled by appropriate mitigation strategies. In both cases, a supplementary cost-benefit analysis may be performed if deemed appropriate.

Safety risks assessed as initially falling in the acceptable region are acceptable as they currently stand and require no action to bring or keep the probability and/or severity of the consequences of hazards under organizational control [17].

B. Fuzzy Multi-Criteria Analysis

To solve the multi-attribute decision-making problem of limited schemes, multiple attribute indexes are generally synthesized to a single evaluation index. So, it is necessary to determine the weighing coefficient of each attribute index [7]. The process of multi-attribute criteria decision-making (MADM) looks for the best of all the existing alternatives. The use of one or another multi-attribute decision theory depends mainly on decision-making situations [8].

MCDM refers to making decisions in the presence of multiple, usually conflicting, criteria. Each different criterion may have different units of measurement, quality characteristic, and relative weight. It is possible that some criteria can be measured numerically, and other criteria can only be described subjectively. Foundations of modern MCDM were developed in 1950s and 1960s. There are dozens of methods available for solving MCDM problems. The MCDM methods are able to provide solutions for a wide range of management problems [9].

Development of MCDM researches accelerated during the 80s and early 90s and seems to have continued its rapid growth.

Despite the fact that MCDM has been successfully applied to various areas of knowledge, it still cannot fully match imprecise, vague and incomplete information. The flexibility, dynamic and receptive nature of MCDM opens a new multitude in leveraging the decision theory. When Bellman and Zadeh, a few years later, introduced fuzzy sets into the playing field, it paved the way for a new category of decision methods to deal with problems which had been inaccessible and insolvable with the standard MCDM technique [19]. When the fuzzy set theory was introduced into MCDM research, the methods were basically developed along the same lines. The first category of fuzzy MCDM contains a number of ways to find a ranking. This includes the degree of optimality, hamming distance, comparison function, fuzzy mean and spread, proportion to the ideal, left and right scores, centroid index, area measurement, and linguistic ranking methods [10]. For purpose of judgement or decision (which words have a clear, definite meaning), we need fuzzy numbers to express linguistic variables, to describe the subjective judgement of a decision maker in a quantitative manner. Triangular Fuzzy numbers (FN), trapezoidal FN and Gaussian FN, are often used [13].

The fuzzy sets theory introduced by Zadeh has been very successful in dealing with problems involving uncertainty. With an increase in inaccurate and vague information in real life problems, several extensions of the fuzzy sets have been developed, one of which is the intuitionist fuzzy set (IFS) pioneered by Atanassov, which has a membership function, a non-membership function and a hesitancy function. Zadeh presented a type-2 fuzzy set that allowed the membership of a given element to be a fuzzy set. The type-n fuzzy set generalized type-2 fuzzy set, thereby permitting the membership to be a type-n-1 fuzzy set [11].

The fuzzy multi-set introduced by Yager allowed elements to be repeated more than once.

Since the concept of the hesitant fuzzy set was established, it has gained increasing attention and has been successfully applied to many uncertain decision-making problems. Many studies have also been conducted on the application of HFS aggregation operators, and distance and similarity measures to multi-criteria decision-making problems [11].

Soft computing techniques, such as Fuzzy sets and Fuzzy logic, Artificial Neural Networks (ANN), and Genetic Algorithms (GA) are useful in handling the uncertainty and vagueness associated with the real-world data [12].

C. TOSIS Fuzzy Method

The TOPSIS method is a multiple criteria decision-making technique proposed by Hwang and Yoon to identify a solution from a finite set of options. Principle of chosen option by TOPSIS is based on the fact of distance (shortest and farthest distance Respectively from positive and negative ideal solution) The Fuzzy TOPSIS technique was proposed by Chen to solve multi-criteria decision-making problems under fuzzy environment and to deal efficiently with uncertainty in the evaluations and judgments. By this technique, the options have to be evaluated with respect to a set of criteria and as the linguistic experts' opinions are subjective, vague, and imprecise in nature fuzzy set theory has to be used, and TFNs can be used to express the linguistic expert's opinions. The steps of Fuzzy TOPSIS can be given as in the following:

Step 1. The importance weight of criteria $\widetilde{wij}$ which describes the aggregated fuzzy weight of the j[th] criterion with respect to the overall goal, Cj (j=1, …,n), given by the Nth decision maker and is calculated by Fuzzy AHP technique will be fed to Fuzzy TOPSIS.

Step 2. Aggregating ratings of options: To build the decision matrix, the linguistic ratings of an option by different decision makers expressed in terms of TFNs have to be aggregated. In case, there are N decision makers, and the rating of the i[th] option for j[th] criterion is = $\widetilde{Xij}$ = (*xija*, *xijb*, *xijc*), the aggregated rating can be expressed by:

$$\begin{cases} \widetilde{X_{ija}} = \frac{1}{N}\ (X_{ija}^1 + X_{ija}^2 + \cdots . + X_{ija}^N) \\ \widetilde{X_{ijb}} = \frac{1}{N}\ (X_{ijb}^1 + X_{ijb}^2 + \cdots . + X_{ijb}^N) \\ \widetilde{X_{ijc}} = \frac{1}{N}\ (X_{ijc}^1 + X_{ijc}^2 + \cdots . . + X_{ijc}^N) \end{cases} \tag{1}$$

Step 3. Building and normalizing the fuzzy decision matrix from the aggregated ratings of options as follows:

$$\widetilde{DM} = \begin{bmatrix} \tilde{x}_{11} & \tilde{x}_{12} & \cdots & \tilde{x}_{1n} \\ \tilde{x}_{21} & \tilde{x}_{22} & \cdots & \tilde{x}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{x}_{m1} & \tilde{x}_{m2} & \cdots & \tilde{x}_{mn} \end{bmatrix} \tag{2}$$

where, $\widetilde{Xij}$ is the aggregated fuzzy rating of i[th] option with respect to j[th] criterion and, i=1, 2, 3, …, m, j=1, 2, 3, …, n. The normalization of the decision matrix $\widetilde{DM}$ has to be carried out by the linear scale transformation as:

$$c_j^+ = Max\ x_{ijc},\quad j \in B;\ \tilde{u}_{ij} = \left(\frac{x_{ija}}{c_j^+}, \frac{x_{ijb}}{c_j^+}, \frac{x_{ijc}}{c_j^+}\right)$$

$$a_j^- = Min\ x_{ija},\quad j \in C;\ \tilde{u}_{ij} = \left(\frac{a_j^-}{x_{ijc}}, \frac{a_j^-}{x_{ijb}}, \frac{a_j^-}{x_{ija}}\right) \quad (3)$$

where, cj+ is used for criteria "with positive effect" and aj− is used for criteria "with negative effect". $\widetilde{uij}$ is the normalized rating of the option, and the normalization matrix is as:

$$\tilde{U} = \begin{bmatrix} \tilde{u}_{11} & \tilde{u}_{12} & \cdots & \tilde{u}_{1n} \\ \tilde{u}_{21} & \tilde{u}_{22} & \cdots & \tilde{u}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{u}_{m1} & \tilde{u}_{m2} & \cdots & \tilde{u}_{mn} \end{bmatrix} \quad (4)$$

Step 4. The fuzzy weighted normalized decision matrix will be calculated by multiplying the weights of the evaluation criteria $\widetilde{WJ}$ by the elements of the normalized fuzzy decision matrix $\widetilde{uij}$ according to:

$$\tilde{v}_{ij} = \tilde{u}_{ij} \times \tilde{w}_j = \left(\frac{x_{ija}}{c_j^+}, \frac{x_{ijb}}{c_j^+}, \frac{x_{ijc}}{c_j^+}\right) \times (w_1, w_2, w_3)$$

$$\tilde{v}_{ij} = \tilde{u}_{ij} \times \tilde{w}_j = \left(\frac{a_j^-}{x_{ijc}}, \frac{a_j^-}{x_{ijb}}, \frac{a_j^-}{x_{ija}}\right) \times (w_1, w_2, w_3)$$

$$\tilde{V} = \tilde{U} \times \tilde{W} = \begin{bmatrix} \tilde{v}_{11} & \tilde{v}_{12} & \cdots & \tilde{v}_{1n} \\ \tilde{v}_{21} & \tilde{v}_{22} & \cdots & \tilde{v}_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ \tilde{v}_{m1} & \tilde{v}_{m2} & \cdots & \tilde{v}_{mn} \end{bmatrix} \quad (5)$$

where, i=1, 2, 3, …, m, j=1, 2, 3, …, n, and the element of $\widetilde{vij}$ is a weighted normalize fuzzy number, and their elements are in the range of [0, 1].

Step 5. Defining the Fuzzy Positive Ideal Solution (FPIS, S+), and the Fuzzy Negative Ideal Solution (FNIS, S−): the positive ideal solution (PIS) allows maximizing the benefit attributes and minimizing the cost attributes. On the contrary, the negative ideal solution (NIS) does the opposite, by minimizing the benefit attributes and maximizing the cost attributes. The option which is closer to the PIS, and farther from the NIS is the leading solution. The (FPIS, S+) and (FNIS, S−) can be defined according to:

$$S^+ = (\tilde{v}_1^+, \tilde{v}_2^+, \ldots, \tilde{v}_n^+),\ \tilde{v}_j^+ = (Max\,\tilde{v}_{ija}, Max\,\tilde{v}_{ijb}, Max\,\tilde{v}_{ijc})$$

$$S^- = (\tilde{v}_1^-, \tilde{v}_2^-, \ldots, \tilde{v}_n^-),\ \tilde{v}_j^- = (Min\,\tilde{v}_{ija}, Min\,\tilde{v}_{ijb}, Min\,\tilde{v}_{ijc}) \quad (6)$$

Step 6. Computing the separation distances of each option from the FPIS and the FNIS to provide a measure of the closeness of the options from the FPIS and the FNIS according to the following equations, which provides separation distance for two TFNs by the vertex method:

$$d(\tilde{v}_{ij}, \tilde{v}_j^+) = \sqrt{\frac{1}{3}[(\tilde{v}_{ija} - max\,\tilde{v}_{ija})^2 + (\tilde{v}_{ijb} - max\,\tilde{v}_{ijb})^2 + (\tilde{v}_{ijc} - max\,\tilde{v}_{ijc})^2]}$$

$$d(\tilde{v}_{ij}, \tilde{v}_j^-) = \sqrt{\frac{1}{3}[(\tilde{v}_{ija} - min\,\tilde{v}_{ija})^2 + (\tilde{v}_{ijb} - min\,\tilde{v}_{ijb})^2 + (\tilde{v}_{ijc} - min\,\tilde{v}_{ijc})^2]}$$

$$D_i^+ = \sum d(\tilde{v}_{ij}, \tilde{v}_j^+),\quad i = 1, 2, 3, \ldots, m,\quad j = 1, 2, 3, \ldots, n$$

$$D_i^- = \sum d(\tilde{v}_{ij}, \tilde{v}_j^-),\quad i = 1, 2, 3, \ldots, m,\quad j = 1, 2, 3, \ldots, n \quad (7)$$

Step 7. Computing the relative closeness coefficient (CCi) of each option with respect to the (FPIS, S+), and (FPIS, S−) using:

$$CC_i = \left[\frac{D_i^-}{D_i^+ + D_i^-}\right],\qquad i = 1, 2, \ldots, m \quad (8)$$

Step 8. Defining the ranking of the options according to the values of closeness coefficients (CCs), in descending order. The best option will be the closest to the FPIS and the farthest to the FNIS [14].

III. Criteria and Index for Selecting the Optimal Option for FDM Risk Assessment

Pilots' operation performance can affect flight safety directly. Many studies have reported that pilot error is the primary cause of over 60% of flight accidents. The statistics on commercial flight accidents in China from 2007 to 2016 indicated that flight crew factors contributed to 63.64% of accidents. An aircraft in flight is affected by many factors such as external atmospheric environments, the aircraft itself, pilots' basic capabilities and skills, pilots' mental state, and so on [15].

The CAST/ICAO Taxonomy Team (CICTT) has defined a taxonomy for aviation occurrence categories, i.e. the categories of occurrence that can take place during an accident or an incident. The aviation occurrence categories:

- RE
- CFIT
- MAC
- LOC-I

are considered a common denominator among the various operational risks to be monitored by EASA Member States. Therefore, standardized FDM-based indicators are defined in priority for these four aviation occurrence categories; however, reference to other categories is made when applicable [18].

Fig. 4 presents an overview of the standardized FDM-based indicators sorted by aviation occurrence category. Some standardized FDM-based indicators are related to FDM event groups identified in the FDM event table of Appendix 1 to AMC1 ORO.AOC.130. This cross-reference figure illustrates this relationship [18].

IV. Model Development and Implementation

The proposed methodology in this paper includes the following steps:

1. Generalizing the criteria and index for assessment of each flight data.
2. Inclusion of a quantitative methods (Fuzzy-TOPSIS

method)

In this paper, the recommended critical factors for considering for safety assessment of flight data according with EASA recommendation (Fig. 4) are grouped into four factors, and each factor includes a subset of them as below:

1. *RE:*
i. High speed rejected take-off
ii. Take-off with abnormal
iii. configuration
iv. Insufficient take-off
v. performance
vi. Unstable shortly before landing
vii. Abnormal attitude or bounce at landing
viii. Hard landing
ix. A/C lateral deviations at high speed on the ground
x. Short rolling distance at landing
2. *CFIT*
i. (E)GPWS/TAWS warning trigger
3. *MAC*
i. TCAS/ACAS resolution advisory
4. *LOC-I*
I. Excessive roll attitude or roll rate
II. Stall protection trigger
III. Excessive speed / vertical speed / acceleration
IV. Insufficient energy at high altitude
V. Low go-around or rejected landing
VI. Reduced margin to maneuverability speed

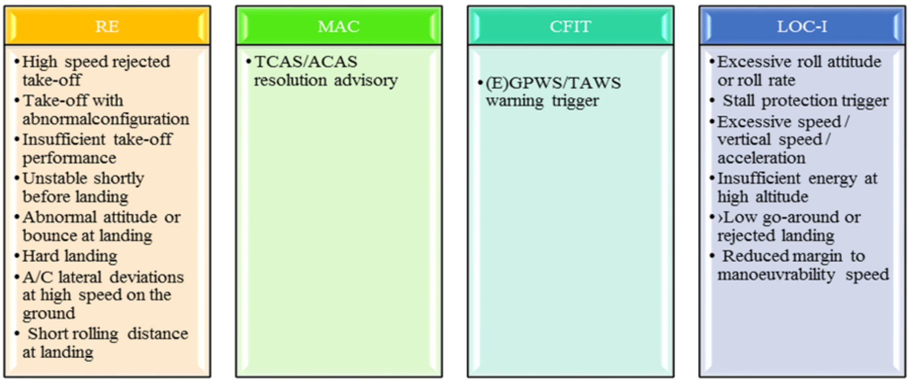


Fig. 4 Standardized FDM-based indicators and aviation occurrence categories for which they are primarily relevant

Definition		severity																				sevirity measurement	probability(Nr of events/Nr of flight)					Risk	result
Factor	index	Class1						weight	Class2						weight	Class3						weight		1-20%	20-40%	40-60%	60-80%	80-100%		
		N/E	1	2	3	4	5		N/E	1	2	3	4	5		N/E	1	2	3	4	5			1	2	3	4	5		
RE	High speed rejected tale-off	557		2				0/1	47		2				0/3	21			3			0/6	2/6				4		10/4	review
	Tale-off with abnormal	39	1					0/1	0		2				0/3	4		2				0/6	1/9	1					1/9	acceptable
	configuration	290	1					0/1	70	1					0/3	4		2				0/6	1/6			3			4/8	accepabale
	Insufficient tale-off	0		2				0/1	0		2				0/3		1					0/6	0/8	1					0/8	review
	performance	93	1					0/1	118	1					0/3	37		2				0/6	1/6		2				3/2	accepabale
	Unstable shortly before landing	84	1					0/1	67		2				0/3	39		2				0/6	1/9		2				3/8	accepabale
	Abnormal attitude or bounce at landing	90	1					0/1	89		2				0/3	41			3			0/6	2/5		2				5	accepabale
	Hard landing	9	1					0/1	4		2				0/3	18		2				0/6	1/9	1					1/9	accepabale
	A/C lateral deviations at high speed on the ground	62	1					0/1	0		2				0/3	0		2				0/6	0/6	1					0/6	accepabale
	Short rolling distance at landing	2		2				0/1	1		2				0/3	1			3			0/6	2/6	1					2/6	accepabale
LOC	Excessive roll attitude or roll rate	557		2				0/1	47		2				0/3	21			3			0/6	2/6				4		10/4	review
	Stall protection trigger	39	1					0/1	0		2				0/3	4		2				0/6	1/9	1					1/9	acceptable
	Excessive speed / vertical speed / acceleration	290	1					0/1	70	1					0/3	4		2				0/6	1/6			3			4/8	accepabale
	Insufficient energy at high altitude	0		2				0/1	0		2				0/3		1					0/6	0/8	1					0/8	review
	Low go-around or rejected landing	93	1					0/1	118	1					0/3	37		2				0/6	1/6		2				3/2	accepabale
	Reduced margin to manoeuvrability speed	84	1					0/1	67		2				0/3	39		2				0/6	1/9		2				3/8	accepabale
CFIT	(E)GPWS/TAWS warning trigger	62	1					0/1	16		2				0/3	3			3			0/6	2/5	1					2/5	acceptable
MAC	TCAS/ACAS resolution advisory	62	1					0.1	16		2				0.3	3			3			0.6	2.5	1					2.5	acceptable

Fig. 5 Flight data Risk assessment model framework

For mutual comparison of index, a few experts in the company must join one another, and their viewpoints should be gathered. To shape this team, factors like enough knowledge for decision-making and organizational familiarity will be on top of all.

To prepare an enquiry about the importance and priority of indexes and factors and prioritizing, numerous questionnaires in the form of matrices provided after normalizing and scrutinizing. In these matrices, rows and columns correspond to factor and indexes. Numbers in each cell in matrices emphasize the priority of the criterion or measure versus others. To complete these matrices, experts will have to make pair comparisons on the basis of the Fuzzy logic and in accordance with Fuzzy numbers as mentioned in Section II. Then, the geometrical average is used to gather the resulting data. After having fully utilized expert ideas and their inference in peer comparisons, the priority of factor and indexes will have developed.

Finally, weight of each factor and indexes and finally the safety risk (according definition of severity and probability of each index which mentioned in DOC9859 as above) of each of them were extracted according to the TOPSIS method (mentioned in Section II). Proposed model is demonstrated in Fig. 5. All numbers in the table are not real and it is filled out as sample to calculate safety risk of each index by implementation proposed methodology.

V. Conclusion and Future Research

FDM can be an effective tool for an operator to improve and monitor its operational safety. FDM was described as a component of an operator's accident prevention and flight safety programme. With the advent of the concept of the (Safety) Management System, FDM is a natural data source for the Management System. Therefore, the use of FDM programmes by aircraft operators is normally checked in the frame of the Management System oversight.

The main purpose of this paper is to set a new approach for assessment of safety risk of flight data based on the Fuzzy TOPSIS method, which composes factor and indexes. by using of multi-attribute decision-making in conjunction with application of fuzzy numbers structure has been regarded as an efficacious method for determination of significance of each factor and indexes. So, these criteria will collectively form a numerical priority with the aid of F-TOPSIS (to precisely make realistic comparisons and inference of each factor and indexes).

The methodology used in this article was selection and weighting of a factor related to flight data via the Fuzzy TOPSIS-based method which composes factor and indexes. Here, using a multi-attribute decision-making (MCDM) in conjunction with application of fuzzy numbers structure has been regarded as an efficacious method for determination of significance of each criteria and options.

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