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Provide a solution for risk analysis in the aviation industry with the help of fuzzy logic and MATLAB software by presenting a practical problem

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Abstract— **The European Aviation Administration (EASA) has already published written instructions for using this method on its website. Airline engineers and design offices use this instruction to estimate the risk in any technical matter before making changes to the design or repair. At present, this method is calculated manually. In this article, we use fuzzy logic. And with the help of MATLAB software, we calculate the amount of risk and risk for a sample design change, and in this way, the amount of risk of all risks in this software can be calculated by considering all related parameters. This article helps. Safety assessment calculations should generally be used as a written program for use in all domestic and foreign airlines and repair centers.**

Keywords-matlab-saftey assessment-risk

Introduction

One of the new methods in estimating the risk in the aerospace industry is the use of safety assessment method. This method is very useful in the aerospace industry and with the help of this method in large companies in the world, the amount of accidents before the disaster is estimated. Pre-design can be avoided with the help of this method to avoid the amount of risks. Aerospace engineers in the aerospace industry can use this method to determine the amount of risk and problems in design changes in cases where access to design information is not available.

A safety assessment, also referred to as "aeronautical study", "safety case" or "risk assessment", is an integral part of risk management and Safety Management Systems. According to ICAO and EASA, safety assessments are required to address safety concerns in case of non-compliances or deviations from regulations as well as prior the implementation of changes in operations or infrastructure.

Risk Assessment is an evaluation based on engineering and operational judgement and/or analysis methods in order to establish whether the achieved or perceived risk is acceptable or tolerable.

Risk is the assessed potential for adverse consequences resulting from a hazard. It is the likelihood that the hazard's potential to cause harm will be realised. (ICAO Doc 9859)

Risk means the combination of the overall probability or frequency of occurrence of a harmful effect induced by a hazard and the severity of that effect. (Regulation (EU) 2017/373)

Description of saftey assessment

Amendments to several Annexes to the Chicago Convention applicable since November 2009 introduced harmonised requirements for the implementation of Safety Management Systems (SMS) by aviation service providers. Aircraft operators and other aviation service provider organisations should establish and apply a formal risk management process within the framework of the organisational SMS. Risk management shall ensure that risks are systematically analysed (in terms of probability of occurrence and severity of hazard effects), assessed (in terms of tolerability) and controlled to an acceptable level (by implementation of mitigation measures).[1]

Aircraft operators and aviation service providers shall also define those levels of management with authority to make decisions regarding safety risks tolerability.

Risk Assessment is the second step in the risk management process. Once hazards and their effects have been determined during the first step by means of hazard identification, an analysis is required to assess the probability of the hazard effects occurring and the severity of these effects on aircraft operation. ICAO Doc 9859 - Safety Management Manual highlights the importance of distinguishing between ***hazards*** (the potential to cause harm) and ***risk*** (the likelihood of that harm being realised during a specified amount of risk exposure).

Risk assessment is based on the evaluation of the following criteria: the severity of a hazard, the probability (frequency) of its occurrence and tolerability of its effects.

Severity of Hazards

The ultimate criterion used to assess the severity of hazards is the impact on the safety of an aircraft and its occupants and other persons who may be directly affected. Elements to be considered in the severity assessment would include a number of indicators, such as crew workload, exposure time to the hazard, aggravating factors etc. Another group factors to be taken into account are the means of mitigation that are considered acceptable by the safety regulator, for example the effective use of Airborne Collision Avoidance System (ACAS) as mitigation means for mid-air collision hazard.[2]

The severity of hazards will be determined by the credible effects on the safety of aircraft, when the outcome of all the weaknesses, potential failures and safeguards (barriers) which may exist in the relevant operational environment have been taken into consideration. For example, the most severe effect (consequence) will only be chosen in such cases when the total system has exhausted its possibilities to affect what continues to happen and only chance determines the outcome, for example the ingestion by aircraft engines of birds greater than they are designed and certificated to withstand and continue functioning where this occurs simultaneously to more than one engine.

Risk Classification

Both probability of occurrence of a hazard effect and the severity potential of that effect, need to be taken into account when deciding on the tolerability (acceptability) of a risk. It is a common practice to use a risk classification matrix in support of this two-dimensional judgement.An example of a risk classification matrix used in ATS is provided below. It has been extracted from ICAO Doc 9859 - Safety Management Manual. Severity is ranked as Catastrophic, Hazardous, Major or Minor, with a descriptor for each indicating the potential severity of consequences. Probability of occurrence is ranked through five different levels of qualitative definitions, and descriptors are provided for each probability of occurrence.

A credible assessment of the severity of hazard effects requires detailed knowledge of the environment of operations and the services (functions) to be performed.[3]

Table 1.risk classification

		Probability of Occurrence				
		Extremely improbable	Extremely remote	Remote	Reasonably probable	Frequent
Severity	Catastrophic	Review	Unacceptable	Unacceptable	Unacceptable	Unacceptable
	Hazardous	Review	Review	Unacceptable	Unacceptable	Unacceptable
	Major	Acceptable	Review	Review	Review	Review
	Minor	Acceptable	Acceptable	Acceptable	Acceptable	Review

Tolerability Assessment

The output from risk classification is used to determine the risks the organisation should act upon. Decision making will require clearly defined criteria about acceptable or tolerable risk and unacceptable risk (see “Acceptable Level of Safety” in Safety Planning article). The assessment of tolerability (acceptability) is critical in making rational decisions to allocate the limited organisational resources against those risks posing greatest threats and this process often may require a cost-benefit analysis. ICAO explains the process of defining risk tolerability by the following:

“Having used a risk matrix to assign values to risks, a range of values may be assigned in order to categorise risks as acceptable, undesirable or unacceptable. These terms are explained below:

Acceptable means that no further action needs to be taken (unless the risk can be reduced further at little cost or effort);

Undesirable (or tolerable) means that the affected persons are prepared to live with the risk in order to have certain benefits, in the understanding that the risk is being mitigated as best as possible;

Unacceptable means that operations under the current conditions must cease until the risk is reduced to at least the tolerable level.”[4]

Various strategies and approaches can be used by aircraft operators and aviation service providers in order to reduce the unacceptable risks to tolerable levels. This third and very important step of risk management is discussed further in the Risk Mitigation article.

Quantitative and Qualitative Methods for Risk Assessment

According ICAO Doc 9859 - Safety Management Manual, there are many options - formal and less formal - to approach the analytical aspects of risk assessment. For some risks, the number of variables and the availability of both suitable data and mathematical models may lead to credible results with quantitative methods (requiring mathematical analysis of specific data). However, ICAO states that few hazards in aviation lend themselves to credible analysis solely through quantitative methods. Typically, these analyses are supplemented qualitatively through critical and logical analysis of the known facts and their relationships.
Federal Aviation Administration in Advisory Circular 150/5200-37 (Introduction to SMS for Airport Operators), suggests that determination of severity should be independent of the probability of occurrence, and vice versa, the probability of occurrence should not be considered when determining severity. Over time, quantitative data may support or alter the determinations of severity and probability, but the initial risk determinations will most likely be qualitative in nature, based on experience and judgment more than factual data.

Description of a real problem

One of the devices that can save the lives of passengers in times of crisis is the oxygen capsule above the passengers' heads.In case of emergency, this capsule automatically releases the musk from the top of the passengers' head by automatically detecting the cabin conditions or by the pilot's order, and passengers can use it in case of lack of cabin oxygen up to 15,000 feet above sea level.

Oxygen capsules have an expiration date and must be replaced. On a Fokker 100 airline, a number of capsules had expired, and the airline was unable to supply the capsules due to the country's sanctions. The technical suggestion was to use the capsules from another aircraft (Fokker 50) of the same family but with a different height ceiling, which is currently ground due to lack of component.

Due to the fact that this aircraft is European and its design information is not available, the degree of risk of this change in design should be done by risk analysis to determine the degree of risk and its feasibility.

Safety risk analysis

Assignment:
Enter the Mission/Project that the Risk Assessment is being prepared for
Describe Hazards:
List each "Hazard" associated with the mission.
Probability (A-E)
Assign the value associated with the "Probability" that the hazard will occur:
Frequent = A
Likely = B
Occasional = C
Seldom = D
Unlikely = E

Effect (I-IV)
Assign the value associated with the "Effect" that would result if the hazard were to occur:
Catastrophic = I
Critical = II
Moderate = III
Negligible = IV

Risk Level (1-4)

Assign the value associated with the "Risk Level" that correlates with the "Probability" and "Effect" for the Hazard:

Extremely High = 4

High = 3

Medium = 2

Low = 1

Pre-Mitigation hazards rate out as:

First list the Hazards. Assign a "Hazard Probability", the "Effect" and the "Risk Level" numerical Value for each. Add up all of the "Risk Level" values (INCLUDING ANY LISTED ON THE CONTINUATION SHEET(s)) and divide by the number of Hazards listed. This fiigure is the rating for "PRE-Mitigation Hazards"

Mitigation Controls:

List the mitigation for each "Hazard" that is listed above.

Probability (A-E)

Re-assign the value associated with the "Probability" that the hazard will occur after mitigation:

Frequent = A

Likely = B

Occasional = C

Seldom = D

Unlikely = E

Effect (I-IV)

Re-assign the value associated with the "Effect" that would result if the hazard were to occur after mitigation:

Catastrophic = I

Critical = II

Moderate = III

Negligible = IV

Risk Level (1-4)

Assign the value associated with the "Risk Level" that correlates with the "Probability" and "Effect" for the Hazard after mitigation:

Extremely High = 4

High = 3

Medium = 2

Low = 1

Post-Mitigation hazards rate out as:

First list the Hazard Mitigation for each "Hazard" listed above, then re-assign the "Hazard Probability", the "Effect" and the "Risk Level" numerical Value for each. Add up all of the "Risk Level" values (INCLUDING ANY LISTED ON THE CONTINUATION SHEET(s)) and divide by the number of Hazard Mitigations listed. This fiigure is the rating for "POST-Mitigation Hazards"

Table2.aviation risk assessment

Risk Assessment Matrix			HAZARD PROBABILITY				
			Frequent	Likely	Occasional	Seldom	Unlikely
			A	B	C	D	E
EFFECT	Catastrophic	I	Extremely				Medium
	Critical	II	High (4)	High (3)	High (3)	Medium	
	Moderate	III	High	Medium (2)			
	Negligible	IV	Medium	Low (1)			

Problem:	Date:2021/01/01
17 oxygen generators packs of Fokker 100 aircraft are expired.	

Describe Hazards:	Probability (A-E)	Effect (I-IV)	Risk Level (1-4)
Problems flying and depletion of passenger cabin oxygen	C	I	High(3)
Pre-Mitigation hazards rate out as:		**HIGH - 3**	

table 3.risk parameters

Solution:	**Date:2021/01/04**		
Interchange of oxygen generator of Fokker 50 with Fokker 100 according to report number EGHAC-DS-PP002-121			
Describe Hazard	Probability (A-E)	Effect (I-IV)	Risk Level (1-4)
May be rate of O2 volume not the same as each other.	D	II	MED(2)
The size of O2 generator may be problem.	D	IV	LOW(1)
Not the separate seat for infant pax.	C	II	HIGH(3)
Different types of connections.	D	IV	LOW(1)
Differences in operation	E	III	LOW(1)
Capsule heating at the installation site	D	II	MED(2)
Use in toxic gas and smoke conditions	E	II	LOW(1)
Impact of overweight capsules on the joints of the installation site	C	IV	LOW(1)
Effect of overweight on aircraft weight & balance	D	IV	LOW(1)
Pre-Mitigation hazards rate out as	**LOW-1.6**		

Approved by	**Head of deign officer**	**Airworthiness manager**	**Monitoring manager**
Name ,Date, sign			

Problem expression in fuzzy logic

Entrance

We did this in order to implement the safety assessment logic of the European Civil Aviation Authority (EASA) in MATLAB software as fuzzy logic.

For the problem in question, we put the declared risks as input. In the figure below, these risks are specified.

Horizontal graph is the percentage of probability of occurrence of each risk. According to the table above, each risk is marked with a letter. These values are obtained from technical reports.

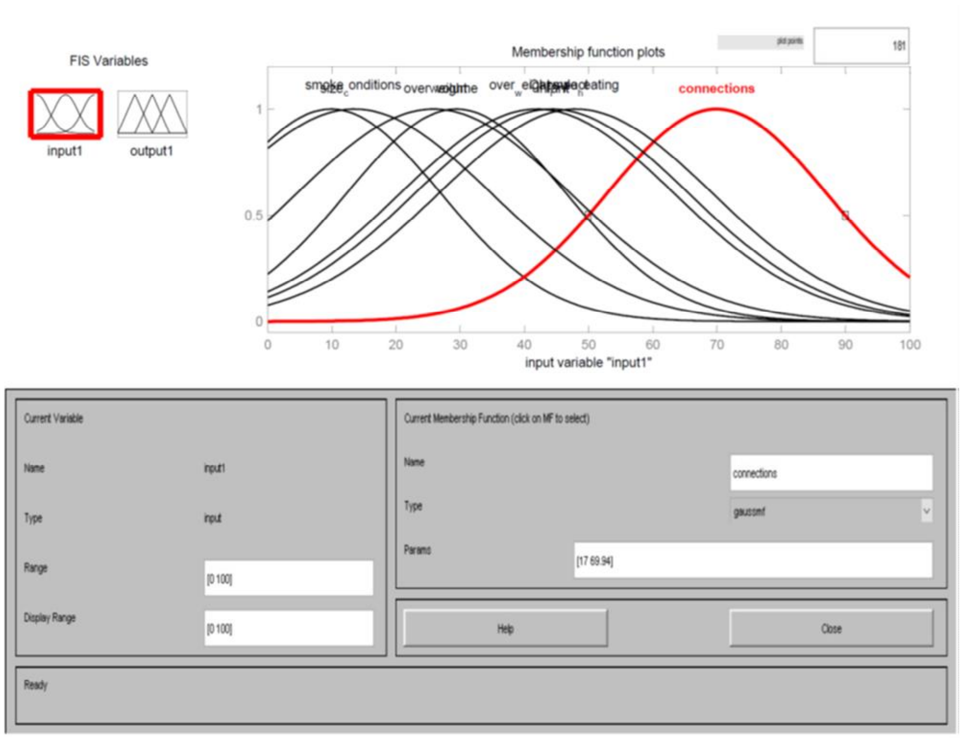

Figure 1.entrance parameters

Table3.precentage probabilty

Item	A	B	C	D	E
Percentage probability	**80-100**	**60-80**	**40-60**	**20-40**	**0-20**

Analysis

To create the conditions for the analysis, we assign a weight to each analysis according to the technical studies and reports, which are expressed under the following headings.

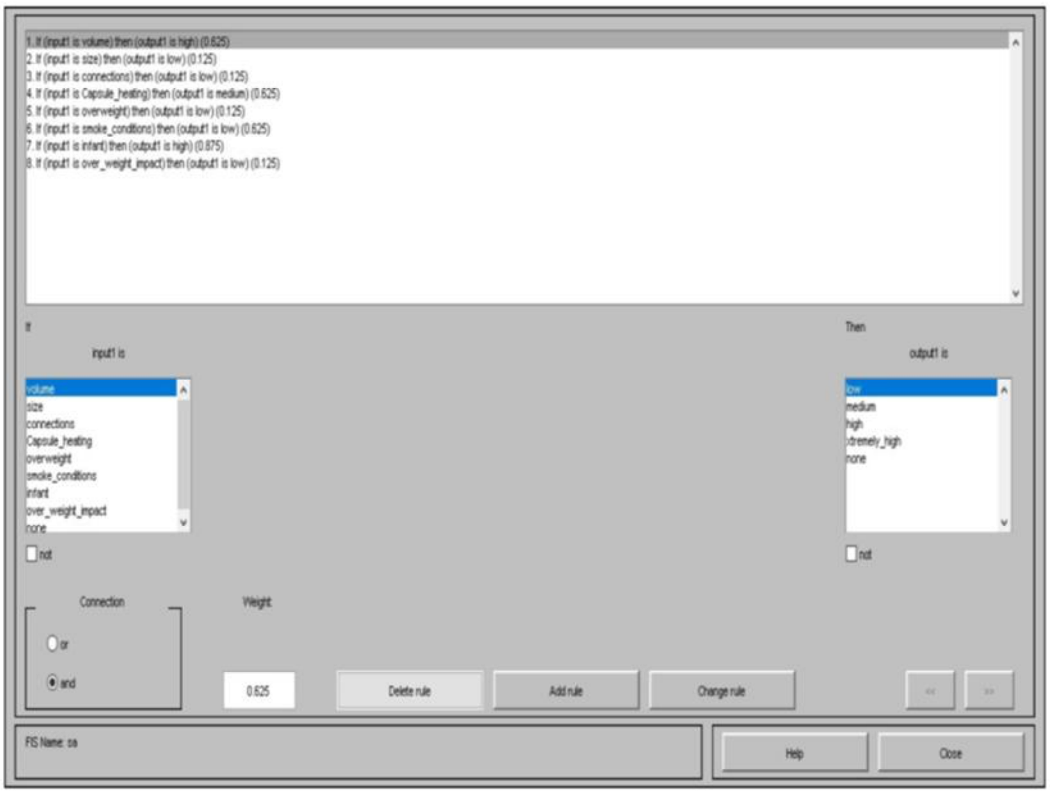

Figure 2.analysis parameters

Table 4.analysis items

Item	I	II	III	IV
effect	CATASTROGHIC	CRITICAL	MODERATE	NEGLIABLE
Effect range	1-0.75	0.75-0.5	0.5-0.25	0-0.25
Weight percentage	0.875	0.625	0.375	0.125

Output

For the output part, we specify the amount of risk for each risk, which is specified in the range of 1 to 4. In other words, according to the table below, each risk is specified as a number and in an interval. The horizontal diagram specifies this range.

Table 5.arisk items

Risk	Low	Medium	High	Extremely high
limit	0-1	1-2	2-3	3-4

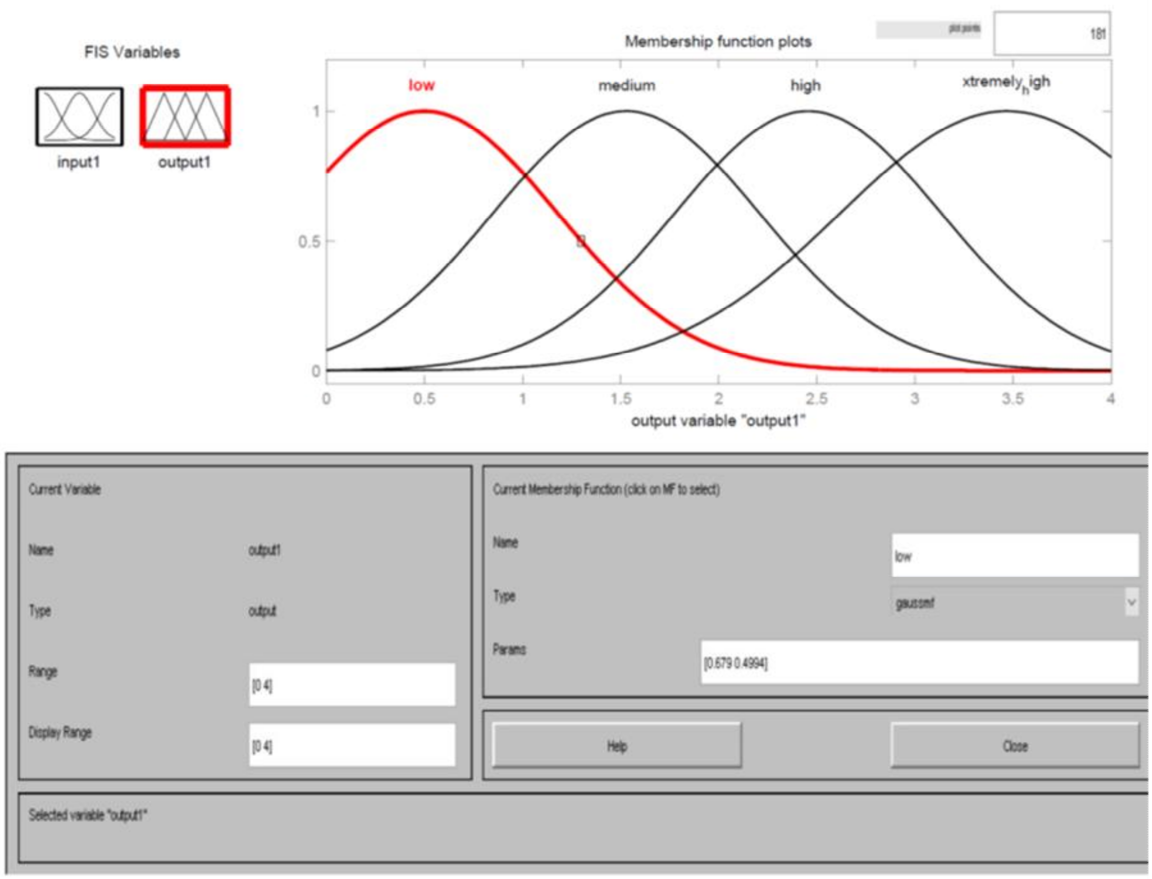

Figure 3.output variable

Result

Now in the result section we can assign the amount of risk to each possibility.

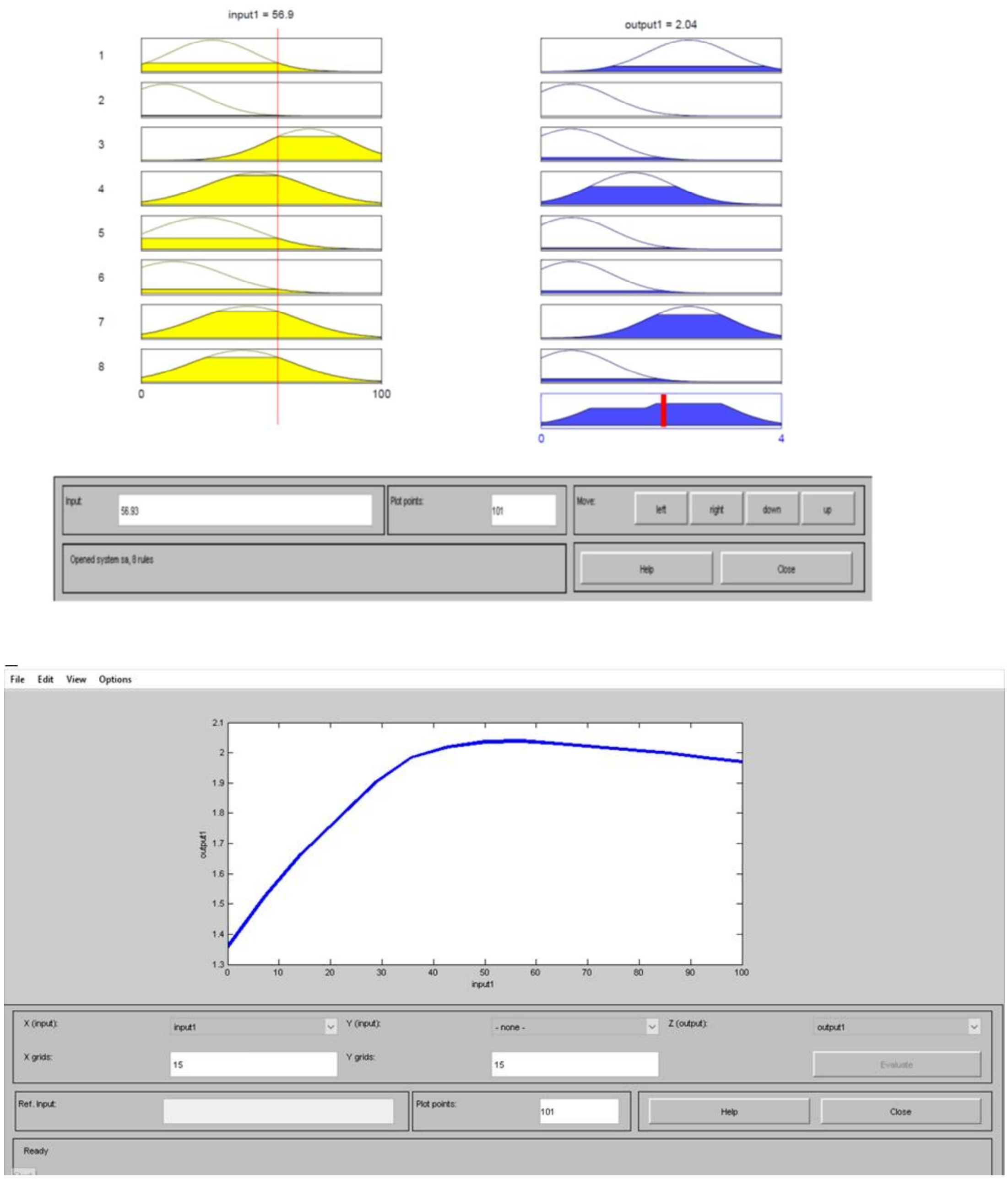

Figure 4.result parameters

As shown on the chart, in all probabilities, the maximum amount of risk goes up to 2, or in other words, to the medium, which indicates that the maximum risk is moderate and can be done, and the risk is acceptable risk.

Conclusion

As it is clear from solving this practical problem, it can be concluded that if we introduce the input parameters in fuzzy logic in the issues related to risk analysis in designing the risk parameters and consider the impact value of each risk as input with the help of fuzzy logic analysis Risk is determined with high accuracy.

This paper presents a solution to reduce human error in aviation risk analysis of design change with high accuracy.

References

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[3].Safety Regulatory Requirement - ESARR 4, Risk Assessment and Mitigation in ATM;
[4].Draft Advisory Material for the Establishment of a Risk Classification Scheme for the Design of the ATM Functional System;